The Institute of Physics

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The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

Institute's Telephone number

Members are asked to note that on and after July 27 the Institute's telephone number will be changed to **BELgravia 6111.**

The Education of Physicists in Universities and Colleges of Technology

The proceedings of the conference on "Degree and Diploma Courses in Applied Physics" which appeared in four issues of the *Bulletin* from February last have now been published under the title *The Education of Physicists in Universities and Colleges of Technology*. A copy has been sent to everyone who attended the conference. Further copies are available from the Institute at six shillings each.

Electronics Group: Conference on Transistors

The Institute's Electronics Group has arranged a conference on Transistors to be held at the Brunel College of Technology, Acton, on September 27 and 28. Papers will be presented by Mr. D. D. Jones, Dr. W. Bardsley, Mr. I. G. Cressel, Mr. J. S. Lamming, Dr. J. M. Kendall, Mr. J. M. Wilson, Dr. A. F. Gibson, Dr. D. F. Taylor and Dr. M. Smollett.

Forms of application will be sent to all members of the Electronics Group; others may obtain forms from the Deputy Secretary.

Electron Microscopy Group Conference

The annual conference of the Electron Microscopy Group will be held at the University College of North Wales, Bangor, on September 10, 11 and 12. Forms of application to attend will be circulated to members of the Group, or may be obtained by others on application to the Deputy Secretary.

Problems of Simple Structures*

By Professor Dame KATHLEEN LONSDALE
D.B.E., D.Sc., F.R.S.
(*University College, London*)

I was born in the year in which the Wright brothers constructed and flew the first successful heavier-than-air machine; and this was also eight years after the discovery of Röntgen rays. I was five years old when Barkla found the *K* and *L* radiations, but I have no reason to suppose that he had any foreknowledge of what my initials would be. When I was nine, von Laue was asking Friedrich and Knipping to attempt their epoch-making experiment on crystal diffraction and ten years later I was one of a packed student audience that listened to W. H. Bragg lecturing on X-rays and Crystal Structure. A few months later he asked me to join his research team at University College and I accepted with alacrity. It was an honour.

Sir William Bragg was then working in the Carey Foster Laboratories as Quain Professor of Physics, and his research team were all young physicists. We affectionately called him "the old man" although he was then only sixty, and at sixty nowadays life is just beginning.

Other members of the team were W. T. Astbury, who took me under his wing and, when we were not discussing crystals, talked to me about his lovely young Irish wife; J. H. Smith, who built a magnificent induction coil inside a drain-pipe and painted Egyptian figures all round it. Later he got a job in Egypt and I don't know what became of him. But it is curious how one remembers all these details and forgets the really useful things like integrals and trigonometrical formulae. Among the others were A. Müller and W. H. Shearer, who had built a simple gas-tube and a photographic powder camera to go with it for an incredibly small sum, using whatever equipment they could find lying around. W. H. Bragg's first ionization chamber was made out of a Cadbury cocoa tin; the "tree" could still be seen on it.

The most valuable person in the laboratory was, of course, Mr. Jenkinson, the instrument-maker. We all called each other "Bill" for some reason, but Mr. Jenkinson was always Mr. Jenkinson, although in his absence we sometimes called him "Jenk." W. H. Bragg had spent part of his share of the Nobel Prize on a first-class lathe and Mr. Jenkinson made all our ionization spectrometers and gold-leaf electroscopes and taught me many useful things, including the art of cutting very thin strips of gold leaf, the best adhesive for which was undoubtedly "lick."

During the years 1912 to 1922 not only had many simple structures been determined but many, I almost think most, of the problems relating to the physics of diffraction had been appreciated, if not solved. Of course a great many of the facts that we now take for granted could not then be assumed. W. H. Bragg, and then Moseley and Darwin, proved that X-rays after diffraction have the same wavelength and are similarly absorbed as the incident beam. Compton later proved that this was not wholly true. Friedrich and Knipping had already demonstrated that the diffracted beams travelled in straight lines, which is more than neutrons do, of course. (Some of the early experiments in which very slow neutrons were totally reflected from mirrors showed that the detecting counter had to be lowered by two centimetres or so to allow for the fall under gravity).

W. H. Bragg first observed the characteristic line spectrum and identified it with

* An Evening Discourse given to the X-ray Analysis Group of The Institute of Physics on November 16, 1956.

Barkla's *K* and *L* radiation, thus paving the way for Moseley's brilliant generalization. But without any knowledge of wavelengths, W. L. Bragg solved the structures of sodium chloride and potassium chloride from Laue photographs only and showed that the guess made by Pope and Barlow had been correct. I wonder how many crystallographers nowadays would like to have to solve structures from their Laue photographs ? When the characteristic spectrum was available, other structures : of diamond, zincblende, pyrites, fluorspar, calcite, were determined—and published—with incredible speed. Modern scientific journals please copy.

Those of us who are acquainted with Sir Charles Darwin find it difficult to realize that it is over forty-two years since he published, in two astonishing papers, almost all that we even now know about the theory of X-ray diffraction from mosaic and from perfect crystals, including the effect of the refractive index. This reminds me of an occasion, some six years or more ago, when the University Grants Committee paid a valued but fleeting visit to my laboratory. When the party had left, one of my students said to another: "You know, some of these old boys are really quite bright. That big chap seemed to grasp what I was telling him about crystal dynamics quite quickly. Have you any idea who he was ? " It was Sir Charles Darwin !

The effect of thermal vibration in weakening the intensities of diffraction spectra had been predicted by Debye a year before Darwin published his theory of diffraction from real crystals. W. H. Bragg verified the effect of thermal agitation and showed the existence of extinction experimentally in 1914 and outlined the elementary theory of Fourier analysis a year later. When I joined his team in 1922 one of my fellow workers, I. Backhurst, was studying the effect of temperature on the diffraction from diamond and graphite, although the structure of graphite was not determined until some years later.

Most of the work done by W. H. Bragg's research team at that time concerned the structures of organic compounds ; W. L. Bragg, in Manchester, was working in the inorganic field. Sir William had measured the unit cells of naphthalene and anthracene in 1921 and had correctly deduced the directions of their long molecular axes. But he found that his calculated density for anthracene was about 10% higher than that recorded in the literature, so the first job I got from him was to measure the density of anthracene. I was a bit alarmed when I got a figure 10% higher than the density given in Tables, and I was most relieved to find that that was just what Bragg wanted.

Then he told me to spend a few weeks reading Hilton's *Mathematical Crystallography* and in the meantime Mr. Jenkinson would make me an ionization spectrometer, complete with the huge lead box by which the Coolidge tube was shielded. It had to be large, because inside this box there was an electric fan to cool the tube. Even with the help of the fan, the anticathode would get red- or even white-hot after a few minutes running. Fortunately our method of taking readings with a gold leaf electroscope did involve intermittent running of the X-ray tube.

We ran the Coolidge tube with an induction coil and mercury interrupter and the periodic cleaning of this interrupter was a filthy job. In the *secondary* circuit there were a milliammeter and a spark-gap, both of which stood on a small insulated table by our side. We had to remember, of course, not to touch it. You may have noticed that my hair has stood on end ever since. The cleaner at the Royal Institution (to which we had all moved in 1923) was very thorough and in spite of warnings she did once try to dust someone's high-tension table ; but it " flashed " at her and she did not do it again.

Our crystals were huge by present-day standards, often 2 mm each way ; and our slit systems were also several millimetres long, a fact which sometimes led to the unfortunate result, unrealized at the time, that a strong first layer-line reflection could enter the ionization chamber and be mistaken for a zero layer-line reflection that was

really absent. And so we sometimes got our space groups wrong.

Talking of space groups, we were no better, or not much better, anyhow, than present-day students at reading the current literature. And although I studied Hilton's *Mathematical Crystallography* with great diligence, and worked out the consequences of space-group theory in terms of diffraction effects, I was for a couple of years quite oblivious to the existence of Niggli's *Geometrische Krystallographie des Diskontinuums* (Leipzig, 1919) and to the fact that this book contained all that I was enthusiastically rediscovering. When Dr. Astbury and I produced our *Tabulated Data for the Examination of the 230 Space Groups by Homogeneous X-Rays* we had great difficulty in persuading Sir William Bragg to allow it to be published, not because it was not really original, however, but because he felt that structures should be worked out by common sense and that arguments based on the theory of space groups were unnecessary. The fact was, of course, that he and his son had really proved the theory of space groups *experimentally*.

Our early attempts at solving simple organic structures were all rather off the mark, because the only clue we had was that carbon in diamond formed tetrahedral and that the *C–C* single bond was 1·54 Å. There were even those who were so impressed by the absence of molecules in inorganic structures that they declared that there were no molecules in organic structures either. But the density of organic molecules showed that if the *C–C* distances in them were anything comparable to those in diamond, then there must be much larger intermolecular distances, of the order of 3 or 4Å.

The difference between the long axes of naphthalene and anthracene crystals showed that the lengths of the molecules must lie nearly along the *c* axis directions, but later observation of the magnetic and optical properties of these two crystals by Indian workers indicated that Bragg's original sideways orientation must be wrong. He also supposed that the carbon rings in these aromatic substances were like the zig-zag rings in diamond, but my own analysis of hexamethylbenzene and J. M. Robertson's more detailed analysis of naphthalene and anthracene showed conclusively that these aromatic molecules were plane and not zig-zag.

Our early attempts to analyse aliphatic structures, however, were much worse. The trouble was that we believed the chemists. Of course, chemists often tell us nowadays that they know all about the stereochemistry of their molecules and that crystallographers do nothing but confirm what they already know. I can only say that I was quite unable to find any chemist who would predict whether the molecule of succinic acid in the solid state would be stretched out or bent double. Like the logical positivists, they parried my inquiry by saying that the question was meaningless, since there could be free rotation about the central single bond. But free rotation or not, I argued that the molecule in the solid state would certainly have some fixed configuration. Then they pointed out that succinic anhydride and maleic anhydride are isomorphous and that since maleic acid is the cis-isomer, succinic acid might well have a cis-configuration also. So I produced a structure made up of hair-pin shaped molecules that seemed plausible, and I got my M.Sc. degree for it, but it was quite wrong. The molecules are now known to be stretched out.

It was not any worse, however, than Astbury's tartaric acid structure, which was supposed to explain the optical activity of tartaric acid both in the solid state and in solution. Incidentally we do not yet, I think, have any satisfactory theory relating optical activity and structure ; certainly not on a quantitative basis. We do not know, for example, why cinnabar has such a large optical rotation. We also know from observation that some crystals belonging to polar classes crystallize in a polar habit and others do not, but we do not know exactly why. We know that the solvent can have a considerable influence on habit and so can temperature of growth. The most striking recent example of the latter effect was shown

by Dr. B. J. Mason at a conference on Cloud Physics earlier this year. It seems that the habit of ice crystals, whether plates, needles or stars, is sharply dependent upon temperature and changes several times in the range 0° to —15°C., in a strictly reproducible way.

I once, in those early days of the ionization spectrometer method, almost embarked on the structure of a protein. One of the staff at University College, London, rang me up and said that they had a beautiful crystal of haemoglobin about 1 mm each way and would I care to make X-ray measurements on it ? I said I would. But it disappeared in the taxi on the way to The Royal Institution, and since then I have always kept to problems involving simple substances, partly because I am still at heart a physicist and partly because I have a firm belief that many of the interesting problems whose significance was realized in those early days of X-ray crystallography have not yet, in fact, been solved. And even where they have been solved, their importance in ordinary structure analysis has not always been realized.

Recently Bijvoet and his colleagues in Utrecht have done a wonderful piece of work in showing that it is possible, in spite of Friedel's law, to determine in an absolute way the structure of an asymmetric molecule. Normally X-rays cannot decide which is a left-handed and which a right-handed form, although the two can be distinguished.

The early problem presented itself in this way: zinc blende grows with some large smooth octahedral faces and some small rough octahedral faces. One kind of face corresponds to a surface layer of zinc atoms, the other to a surface layer of sulphur atoms. But how can we tell " tother from which " ? Coster, Knol and Prins solved this problem twenty-six years ago by using the *L* spectrum of gold as an incident beam and observing the effect of the phase change introduced by the *K* absorption edge of zinc, which lies between the gold La_1 and La_2 lines (*The Crystalline State*, Vol. II, p. 33). They found that the big faces were sulphur, the small ones zinc. When pressure is applied to a zinc blende crystal normal to these octahedral faces, the sulphur faces acquire a positive and zinc faces a negative charge.

Bijvoet, using a similar principle, tested what the chemists know as the Fischer convention. Chemists really could not tell whether in the case of the tartrate group, for instance, the dextro form, which in solution rotates the plane of polarization to the right for light of a given wavelength, was in fact a clockwise arrangement of the carboxyl, hydroxyl and hydrogen groups (looking towards the carbon atom to which they are attached) or an anticlockwise arrangement. The Fischer convention laid down that it should be supposed to be a clockwise arrangement, and there was a 50 : 50 chance that this was correct. Fortunately for the textbooks, Bijvoet's experiments using zirconium $K\alpha$ radiation showed that it was so for dextro-sodium rubidium tartrate and this fixes the absolute configuration of many other optically active compounds.

We now know that it is not necessary to use exotic characteristic radiations in order to carry out these experiments. Even with copper $K\alpha$ radiation, the anomalous dispersion effect for bromine (a rather common " heavy atom ") is large enough to produce 25% difference in diffraction intensity from (hkl) and $(\bar{h}\bar{k}\bar{l})$ in some cases, the difference being in different directions ($I_{hkl} \gtrless I_{\bar{h}\bar{k}\bar{l}}$) for different pairs of planes. Peerdeman, for example, has shown in this way that *natural* strychnine has a left-handed configuration of atoms (*Acta Cryst.* **9**, 824 (1956)).

But this is not the whole story. Strychnine is hardly a simple compound by my definition ; yet even for much simpler compounds dispersion corrections can be important and are sometimes wrongly neglected. A structure has recently been published for cinnabar, mercuric sulphide, which completely ignores the dispersion corrections for mercury, yet in fact the correction factor at high diffraction angles is not much smaller in magnitude than the actual scattering factor for sulphur, and the alteration of phase angle due to the influence of the imaginary part of the dispersion is considerable.

Dauben and Templeton (*Acta Cryst.* **8,** 841-2 (1955)), have recently pointed out that while the neglect of dispersion corrections may not lead to any significant errors in atomic co-ordinates, yet the determination of atomic vibration amplitudes and of electron density distributions may well be affected. And it is essential, if we are really to understand the forces that control the formation of molecules and of crystals, that these vibrations and distributions of electron density shall be accurately studied.

It was realized and experimentally proved by James and Firth, and by Brindley, many years ago, that in structures such as sodium chloride the sodium and the chlorine atoms are vibrating with different amplitudes. Given that we may define B^T in the expression

$$F^T = F_R^T \exp\,(-B^T \sin^2\theta/\lambda^2)$$

as the Debye factor for the reflection *hkl* (F^T is the actual structure factor at the given temperature, F_R^T the same for a structure in which all atoms are at rest), this would mean a variation of the Debye factor as between reflections having all even and all odd indices. If the vibration amplitudes of atoms in a simple structure are very different or are anisotropic, F_R^T/F^T may be positive or negative, and $\gtrless 1$.

If one measures diffraction intensities from the same crystal at several different temperatures it is apparent that some reflections show much bigger intensity changes than others. Part of these intensity changes may be due to an actual change of the atomic co-ordinates, especially in cases where a change of orientation of a molecule is possible as, for example, for naphthalene or anthracene. Part of the change is certainly due to a decrease with temperature of the anisotropic thermal vibrations of the individual atoms. But which is which can only be determined by a combination of different kinds of measurements and of computations, and if we are to disentangle these various effects satisfactorily, then the simpler the structure investigated, the better.

Now the theoretical chemist wants to know, as exactly as possible, interatomic distances and bond angles. There are, for example, some ten different theoretical models for the anthracene molecule, counting the one in which the condensed rings are regular hexagons. Can the crystallographer say for certain which is correct, or even which is to be preferred on the basis of his experimental data ? That depends partly on the accuracy of his intensity measurements : 10% is not good enough nowadays. It seems likely from comparisons now being made in my laboratory that using very small crystals of negligible extinction, photographic intensity measurements made visually for different crystals of the same substance can be expected to agree to $<4\%$, perhaps even to $<3\%$. Geiger counter measurements may do even better.

A serious possibility in the case of data collected from several films or from different layer-lines of the same film is the existence of " patchiness "—groups of systematic or non-random errors. Unfortunately it seems that these non-random errors may result in an under-estimation of the mean standard deviation. This possibility of under-estimating our probable errors in crystal structures derived from unreliable data is serious because some chemists, at least, do take us very seriously.

Even if good data are available, however, it may still not be possible to decide between various theoretical molecular models. This is being put to the test now by my colleagues, Drs. H. J. Grenville-Wells and R. Mason. They have collected new data for anthracene and starting from the molecular orientation given by Mathieson, Robertson and Sinclair (*Acta Cryst.* **3,** 245 (1950)) they are testing each of the ten theoretical models in turn, refining both atomic co-ordinates and anisotropic atomic vibrations by a combination of least squares and difference Fourier methods, to see whether their refinements *converge* on any one of the models.

In these and similar processes of structure refinement it is wise to include *H* atoms as soon as the structure is worth refining at all. The danger is that, as Dr. Grenville-Wells has proved to my satisfaction at least, it is possible to refine without the *H* atoms

up to a point, but if on including H the reliability factor

$$R = \Sigma (| F_c | - | F_o |) / \Sigma | F_o |$$

increases (F_c calculated, F_o observed structure factor) then the atomic co-ordinates are almost certainly wrong in some respects. The same applies to anisotropic atomic vibrations ; they should certainly be included at an early stage of refinement.

If it is possible to obtain really accurate bond lengths, vibration amplitudes and electron density distributions, then it may be possible to hope for a positive answer to the question as to why some substances have physiological effects that are *not* possessed by other closely similar structures, or possessed in different degree. Does the carcinogenic potency of certain quite simple aromatic compounds depend upon the presence of a so-called *K* region which is especially active and which is characterized by a very short *C–C* distance ?

The X-ray methods of determining anisotropic atomic and molecular vibrations should give results of interest to the spectroscopist, especially if it is possible to distinguish between lattice and intramolecular vibrations and between thermal and zero-point energy as we hope to do. It is, of course, difficult to sort out thermal vibration effects from the effect of non-spherical electron density, especially at room temperatures. In our work on urea (*Acta Cryst.* **9,** 697, 709, 1956)) Dr. Grenville-Wells applied McWeeny's scattering factor for oxygen as meaning that the electron density distribution is a prolate spheroid having its long axis along the $C = O$ bond ; but this is somewhat doubtful. What the electron density actually is depends on the amount of double bond character and the relative strengths of the two pairs of hydrogen bonds in urea, which attach the oxygen to its four neighbouring nitrogen atoms. Whatever the electron density is, it is liable to be confused at room temperatures with anisotropic thermal vibrations, and therefore low temperature determinations of structure give a better hope of determining the angular dependence of the electron density distribution and thence the correct asymmetric structure factor to be applied.

Another way of arriving at rest values of electron density distributions is to subtract the thermal vibrations determined by neutron diffraction methods from the Fourier map of the substance as determined by X-rays. But if this method is to be reliable the atomic co-ordinates given by each technique must agree very accurately. Even for urea this is not yet the case, although they do just overlap within the limits of error given.

The trouble about a good deal of this work is that it must be done by experienced and accurate research workers and yet most of it consists in doing again what someone has done, less accurately, before. What is needed is a systematic repetition of the analysis of key simple structures, using X-ray, electron and neutron methods at various temperatures, measuring also the coefficients of expansion, the effects of isotope substitution, the anisotropic optical and magnetic properties, and so on. Not only are experimental data of maximum accuracy required, but there is still the need for experimentation with various theoretical treatments of these data.

Crystallographers are apt to become hilarious when anyone publishes a new analysis of, for example, oxalic acid dihydrate, but the fact is that neither oxalic acid dihydrate nor any other simple organic crystal structure has yet been satisfactorily determined. This reminds me of the only time, I think, when I saw Sir William Bragg really angry. It happened that some bumptious young man, in Sir William's hearing, spoke scornfully of the work of the late Dr. Eumorphopoulos, so much beloved of the students at University College, London, because of the interest he took in their welfare. Dr. Eumorphopoulos had spent many years determining the boiling-point of sulphur, pushing the accuracy further and further and never being satisfied with his latest result. The bumptious young man thought this was a waste of time ; but Sir William turned on him and said that, on the contrary, such workers were the salt of the earth and that their results would stand

and be of value when their ignorant critics were long forgotten.

Apart from organic structures, many facts about inorganic structures still remain to be studied. Take quartz, for example. The only Fourier analysis, so far as I know, to have been published, that of Brill, Grimm, Hermann and Peters, indicates that the silicon and oxygen atoms occupy roughly equivalent amounts of space. Is this because there is 50% ionic character, or because a small silicon ion is vibrating more violently than the larger oxygen ion? We do not know anything quantitative about the quartz thermal vibrations, but the heights of the Fourier peaks do not seem to indicate much silicon motion. We might understand transformations better if the thermal vibrations were studied on each side of the transformation point. Recent work on cubic and amorphous forms of ice (Lisgarten and Blackman, *Nature* **178,** 39 (1956)) indicates the difficulties as well as the possibilities of this kind of investigation, for even in the hexagonal form of ice the relatively random arrangement of the hydrogen atoms has only recently been established with any degree of certainty ; and although diffuse scattering patterns indicate an interesting distribution of thermal vibration amplitudes, little is yet understood of the relation of these to the structure.

So far I have only outlined a very few of the problems involved in the study of simple structures. I have scarcely mentioned order-disorder phenomena, the effects of irradiation, the diamond mystery. Frank (*Proc. Roy. Soc. A* **237,** 168 (1956)) has recently suggested that the extra spots observed on the diffraction patterns of many diamonds may be due to segregated silicon impurity atoms. If this be so, we might hope to study the effect systematically in germanium-silicon alloys containing very small, but known and varying amounts of silicon, suitably heat-treated.

I called my discourse Problems of Simple Structures, but that is really a misnomer. There are no simple structures.

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Graduate Physicists in Industry*

By M. MILBOURN, A.R.C.S., D.I.C., F.Inst.P.

(*Imperial Chemical Industries Ltd., Metals Division, Birmingham*)

In 1925, the late Professor Callender advised his newly graduated students to "get out into industry." At that time, this was unexpected but far-sighted advice, because the part that physicists could play in industry was not then fully appreciated, and the scope of their employment has increased very considerably over the intervening years. The future demands of industry for physicists are very likely to increase, particularly as some of the more startling industrial developments have a physical basis. It is relevant, therefore, to discuss the knowledge and mental qualities that industry looks for in the graduate physicists it recruits.

The general plan to be followed in this talk is to discuss firstly why physicists are employed, what type of activities they are engaged in, and how they operate. From these considerations, the requirements of industry with respect to physicists will be formulated, and finally some observations made on university courses.

Before discussing why physicists are employed, attention must first be given to reasons for the employment of scientific graduates generally, and to distinguish between the objectives of industrial, university and scientific civil service work. At a university the object is to extend boundaries of knowledge, coupled with the education of undergraduates. There is, however, a general discipline of postgraduate research, defined loosely by the requirements for a thesis or for publication in recognized journals. Research workers gladly submit themselves to this discipline, which is largely traditional, and gain their rewards from the personal satisfaction of having made contributions to knowledge, and of having acquired the respect of their colleagues. In the scientific civil service the objective is to seek new and better ways of performing certain operations, preferably economically, but not necessarily so.

In industry on the other hand, the primary objective is to maintain a Company in operation, for which purpose the profit motive comes uppermost. In twenty or thirty years' time, the range of products and the manufacturing methods of a specified industry are likely to be substantially different from those obtaining at present, and the changes will arise from research and development work now proceeding or to be undertaken within the next few years. Current investigations must, therefore, be directed to the maintenance of profitable production. The industrial scientist, who undertakes such investigations, submits himself to a discipline different from that of the university investigator, but one that is equally rewarding. There is, for instance, great satisfaction in seeing the consummation of one's activities in a new plant, a new product or a piece of new equipment. The profit motive, in fact, is a stimulation to direct one's thought and work into useful activities, which call for as high a level of intellectual ability as research in a university. Although objectives may be different, parts of the route by which these objectives are attained are identical. Thus, in industrial work, the significance of previous investigations must be established and experimental work conducted, although the field which experimental work is allowed to cover may be limited.

Turning now to the reasons for the employment of physicists as such, they clearly have a

* Based on a lecture given at The Scottish Conference on Training in Physics held by the Institute's Scottish Branch and Education Group in Glasgow, April 12-13, 1957

major role in electronic, instrument, electrical and similar industries. In other industries, they may well be engaged primarily because their training has provided knowledge and skills which are of value as an ancillary service to the work of chemists, metallurgists or engineers. They may be investigating, for instance, such problems as crystal structure, lubrication, colour or mechanical properties, but the nature of the problems on which they will be working in five years' time cannot be predicted. For this reason, industry is not seeking graduates with specialized training, but those who have a thorough grasp of the fundamentals and logic of their subject, which they can apply to a variety of problems. The physicist's particular merit, in fact, lies in his combination of precise observation, design and use of instruments, the formulation of results in mathematical terms, and the alternation of hypothesis and experiment. Admittedly, this is no more than scientific method, which is itself basically physical, and has spread into other sciences, as instanced by physical chemistry, physical metallurgy, biophysics and agricultural physics. I would suggest that herein lies the main reason for employing physicists, because anyone thoroughly grounded in scientific method and with an intellect trained to think logically in this manner, will have acquired the ability to undertake an increasing range of work and to become a more useful employee as his experience grows.

A young graduate straight from university will usually be given an assigned task, most probably of a research/experimental nature, which he will pursue under limited direction. He will be expected to make some contributions to his work in the way of improved equipment, more accurate results, or the general plan of the investigation. He should be able to bring the work to a logical conclusion, and to write a clear and informative report on the subject. He may be working in any field of classical or modern physics, but he will undoubtedly be given opportunity for making himself thoroughly familiar with the background of the work he is conducting. He should therefore know something of books, journals, abstracts and how to survey them. From his very earliest days he may be assigned responsibility for junior staff, guiding them in subsidiary activities or enlisting their co-operation in his own work. Thus, a man engaged in determining crystal structures by X-ray crystallography may supervise the work of a junior in the identification of materials by X-ray means. After a few years, he may be asked to serve on a committee, where he will represent his employers and express their views. This calls for attributes of co-operation and expression, the ability to accept the views of others and to make quick assessments and decisions.

As he progresses, he should be able to work with less and less supervision, and, in fact, he will be expected and encouraged to visualize problems which his capabilities and experience can help to solve. For example, in corrosion investigations, a colleague of mine has reverted to the examination of metallic surfaces in polarized light as developed by Drude in 1896. He had found that X-ray and electron diffraction techniques were inadequate for studying the initial formation of oxide films.

A physicist's work is unlikely to be of a fundamental nature. Sir John Cockcroft has stated that approximately 20 per cent of the work at Harwell is in basic science and of a long-term nature, and that the remainder is applied science or development directed towards specific practical objectives. The relative proportion of fundamental work in industry would certainly be no higher and may well be lower. Although the physicist will, therefore, be applying principles, theories, and methods developed in academic spheres, the knowledge he requires may be none the less esoteric. Again to quote an example, studies of surface chemistry call for considerable knowledge of the theory of semi-conductors. Applied physics may well be making advances in knowledge along specified directions, but the investigator will require considerable judgement to know whether the side-channel which his investigations reveal, and which would very probably be studied in university research, can be followed advantageously or whether it is merely interesting.

Industrial investigations usually follow a logical experimental pattern, but there is also room for the inventive approach, which relies on inspiration without necessarily being logical. University courses, however, are not designed to develop the inventive frame of mind, which rightly falls outside their ambit. Nevertheless, a worthwhile patent or similar advance in efficiency is a likely end product of any investigational work.

Every employee is interested in promotion and advancement, and there are two routes open to the physicist, depending on his personal predilection. The first is that he should become a specialist in a restricted field ; mass spectrometry, creep and fatigue of metals, or nuclear magnetic resonance may be quoted as typical examples. To do this he must show by his enthusiasm and ability that he is fit to become a specialist and that he can thereby make a useful contribution to the activities of his employers. Financial rewards for the specialist can be considerable, although necessarily not at the highest level. Personal satisfaction can be of a high order in keeping abreast with developments elsewhere, attending specialist conferences, and serving on committees.

The other route to advancement is by way of increasing responsibilities for the work of other people, possibly leading eventually to a managerial or directing position. Many technically trained people follow this route, and the proportion of graduates who fill high managerial posts is increasing. In my own Company for instance, two thirds of the top few hundred are technically trained people. To fill such a post a physicist requires his trained intelligence and many other attributes as well. I can quote two examples where logical thinking is certainly required. Metal rolling involves the conversion of a slab into a long length of thinner material, employing a variety of rolling and annealing equipment. The determination of the route by which conversion is effected most economically requires consideration of plastic deformation, crystal structure, annealing characteristics, control of gauge, the quality of the finished material, and the inter-relationship of these factors with available plant. In other words, the complete process must be viewed as a whole, decisions made as to what information is needed from experimental or observational work, and the co-operation of many people sought. Another example can be quoted from the field of chemical engineering in which the implications of using a cheaper raw material may be needed. It may crush or filter in a different way from the established grade, or it may contain different impurities which necessitate process modifications. Once again the overall picture must be considered by a man of high intelligence.

While advancement may mean that a physicist has to depart from a strict study of physics, it does not mean that he will relinquish the intellectual ability that he has gained thereby. It will, in fact, be his most valuable asset, and students who are now passing through universities will be called on to fulfil more complex tasks in twenty or thirty years' time than people of my generation. Other attributes will also be required of which the most important is judgement, used in defining an objective, and in determining the best route by which that objective can be attained.

The question as to how a physicist is employed can be dealt with briefly. He will generally be a member of a team, but teams can be organized in different ways. For instance, a metallurgist, an engineer and a physicist may be formed into a group and given a problem to solve. Another type of organization, with which I am more familiar, is that in which teams of analysts, crystallographers, corrosion chemists and metallographers are formed, and while conducting their own researches, also co-operate actively with metallurgists in solving metallurgical problems. Each individual, therefore, has responsibilities not only up and down the organizational line, but also horizontally to his opposite numbers in other sections. This calls for co-operation and for the ability to discuss problems, and to pursue them along a course someone else may define.

Having now said something of the activities of physicists in industry and of the way in

which they are expected to operate and advance, we can consider the attributes which industry seeks in recruiting staff.

Firstly, of course, a physicist is expected to have a thorough grounding in his subject, but it must be emphasized that this should be a firm grasp of fundamental principles, rather than acquisition of knowledge and facts, so that he can undertake a variety of assignments. The opportunities for further training can frequently be found in postgraduate courses, or in periods spent at other laboratories. Contacts with his colleagues should also widen his outlook considerably. Observational and experimental skills are of value, because a physicist is likely to be engaged in the first place on work of an experimental nature. In later life, however, when laboratory work may have been largely relinquished, such skills still retain their value, in appraising and guiding the work of others, in observing the operation of a manufacturing plant, and in assessing tabulations of results or other figures.

While a period of university postgraduate research provides further opportunities for developing the intellect, this may be effected equally well during the first few years in industry if one is working with or for people who are themselves of good ability. Records of established personnel indicate that, after ten or fifteen years, it seems to be immaterial whether or not a doctorate has been obtained.

Training in mathematics is valuable, but it does not replace the need for experimental ability. Mathematics, in fact, is no more than a tool to provide a formalized approach to logical thinking. An appreciation of statistics and of statistical methods is desirable because it indicates the nature of variability and of errors. In industrial work, experimental results seldom have the accuracy of those on which the teaching of physics is based, because the materials and processes encountered are never perfect or homogeneous. This can be one of the hardest lessons for a young graduate to learn, but I would not recommend that the standard of perfection taught in universities should be lowered in consequence, although it should be combined with an appreciation of inaccuracies likely to arise in applied work.

Ability to use knowledge acquired formally or through experience is important, not only because a young graduate is expected to make positive contributions to the tasks assigned him, but because he will be applying his knowledge in a much wider sense if he becomes the assignor rather than the assignee, the giver and not the receiver of instructions. There is perhaps a tendency to believe that a complicated approach using the most up-to-date methods and equipment should be used preferentially. Instances certainly arise in which this is so, but if there is a simple and direct alternative, it will usually be found to be more rewarding.

The attributes already mentioned are concerned directly with scientific method, but there are several other more personal attributes which industry looks for and which are outside the scope of scientific method, or are only loosely connected with it. The most important, as has already been indicated, is judgement, which is admittedly acquired largely by experience, but the seeds of which are undoubtedly sown quite early in life. It may be described as a facility for summing up a situation objectively and for knowing which way to proceed. It also involves making the best use of incomplete information, extracting from it all that is possible. Furthermore, an immediate project must be viewed against a background of production, commercial and economic possibilities, viewing the whole with a sense of proportion. Self-criticism also forms part of judgement, directed towards making sure that recommendations and conclusions are justified and will be advantageous if implemented. At least one can be sure of being informed if they are not.

Initiative is another important attribute. It implies the ability to see the existence of a problem, to formulate a line of attack, to ensure that work is progressed correctly either by oneself or by others, and to report it clearly and expeditiously. It also involves powers of expression in presenting various stages of thought to other people, generally one's superiors, so that they may play their role in the implementation of projects.

As promotion generally involves taking responsibility for the work of others, leader-

ship is a necessary quality for those who wish to advance. A leader must not only indicate what should be done, but he must also encourage and inspire his staff and point out to them respects in which they are not making the grade. Leadership also involves the passing on of information and instructions where appropriate, and taking one's full and proper place in the organizational tree.

Other attributes which may be looked for include administrative ability and co-operativeness. Thus a man must be able to organize his own work from his very earliest days, and later to organize the work of others and to integrate it with a team effort. He should be able to make his views acceptable to others and should not resent criticism when it is justified.

Having indicated how physicists are employed in industry, and the attributes which they should have, attention may now be given to the young graduate, and the qualities he may be expected to acquire at a university. A course in physics should concentrate on basic principles, the relationships between various parts of the subject, and the logical development of physical thought. It should, in fact, be designed to provide a student with an armoury of weapons, rather than to show him how to use them, although, of course, their purposes must be discussed. Industry can make provision for training in specialized matters, but it cannot provide the intellectual ability which should be the outcome of a university course in a basic discipline. The man destined to become a specialist should not be singled out while a student, because only subsequently will he show by his own choice and ability that he is fitted for a specialist activity, in which he will need the same logical, far-seeing approach as the man who is going to advance by expanding his sphere. Industry, in fact, is looking for educated men, and not for trained men. The title of this conference, which is on " Training in Physics," is perhaps somewhat misleading.

At first sight, it might appear that, as industry is making use of physicists in applied fields, their training should be in applications. The argument is fallacious, however, because applications cannot be foreseen even over a limited period of about five years. In twenty years' time, physicists will be using fundamental work which has not yet been carried out, and they will need a thorough grounding in principles to be able to keep up to date. The student should be made aware of the scope of applied physics, through illustrative examples; the suggestion has already been made that a statistical approach to results may be advantageous.

There is perhaps a tendency for undergraduates to believe that an industrial career is only second best to an academic career, and that the profit motive may be frustrating. The intellectual challenge of industrial problems, however, is at least as great as those found elsewhere, and will increase as the years go by. Willing submission to the discipline of the profit motive, in the same way as the postgraduate man submits to the discipline of university research, can result in stimulation and satisfaction. Frustration can occur in all walks of life, and I doubt whether it is more prevalent in industrial than in academic spheres. The technical knowledge gained by physicists is basic to many industries; the nature of their studies should provide them with good intellectual ability, and they should therefore be well suited to industrial careers.

Reports written by young graduates are frequently of a lamentably low standard, the fault being not so much incorrect English usage, as inability to convey a logical exposition, with particular reference to reasons for the initiation of the work, its relationship to allied investigations and the conclusions drawn from it. Clarity of thought seems to be lacking, as well as clarity of expression, indicating that the course of study has not instilled logical thinking, but has concentrated more on the acquisition of facts and knowledge. Universities might well take some action to correct this situation. Training in English is rightly the responsibility of the schools, but one possible action which could be taken at universities is to criticize students' essays more severely, adopting the attitude of a referee for publication in a recognized journal. The man who can write

a good report is bound to win the commendation of his seniors thereby, and is a very likely candidate for promotion.

Considerable attention has been given in the earlier parts of this talk to the personal qualities of judgement, initiative, leadership, administrative ability and co-operativeness. While these develop with experience and become more and more important with advancing years, there is an indication that their seeds are sown in early life, and that some steps can be taken to encourage and develop them at universities. When these attributes are in operation, they reduce very largely to personal contacts between the individual and other people in all walks of life. The arts graduate or the student of the humanities is reputed to be good at personal relationships, but there are several posts of high responsibility in industry which call for knowledge and skills that only scientists can acquire. The non-scientific side of personality can be nurtured at a university by the lively interchange of thoughts and ideas between people who are following different studies, and by taking part in any of the multifarious student activities, as well as by participation in departmental colloquia. Formal lectures on such matters as musical and artistic appreciation are no substitute for direct personal activity, but the one may stimulate the other.

The future position with regard to National Service is rather confused at present, and no good purpose would be served by discussing its implications in detail. Our experience has been that, in a period of National Service, a young man gains more through developing his personality than he loses through forgetting some things he has learnt. He generally regards it as a waste of time, and cannot be persuaded that it is likely to do him good. If it is discontinued in the near future, attention could well be given to the use of vacation courses for developing the personality as well as for extending technical ability. The engineer learns more than how to handle machine tools during his period of shop-floor training.

Much of this talk applies to graduates in general rather than to physicists in particular, because the man with good mental qualities generally emerges as superior to the man with good knowledge only. After several years, in fact, the sharp distinctions between those who have followed different studies become ill-defined. The usual failing of graduates is that they lack clarity of thought and the consequent sense of judgement, but there are not many who are complete failures. Several find themselves eventually in intermediate positions where they can fulfil a useful purpose with a good measure of satisfaction. For advancement to posts of high responsibility there is a constan demand for people combining good technical knowledge with intellectual ability and fully rounded personalities. In general, it is up to the individual to decide where he wants to go, how he wants to get there and what attributes he must obtain to fulfil his ambition. Those who aspire to be directors or managers in twenty or thirty years' time will certainly find that they need all the skills they can command.

Reviews of Books

THE NATIONAL GALLERY, January, 1955 — June, 1956

London : The Trustees of the National Gallery. Pp. 105. Price 10s.

Similar in format to the one which covered the years 1938-1954, this survey reviews the more recent activities of the National Gallery and describes the proposed reconstruction of the building which will provide more hanging space—properly lit and air-conditioned—and house the Conservation and Scientific Departments in quarters which will be functionally more suitable for their activities. The value of air-conditioning as a means of stabilizing the hygroscopic materials in paintings is forcibly brought out by comparing the low " sickness rates " among those hung in controlled atmospheres with what occurred to those in other parts of the building ; for the latter it became necessary to

provide an emergency "hospital" to deal with the "bumper crop of cracked panels, blisters and flaking paint." It is not only the pictures which benefit from the improved conditions since the public are able to see the paintings without glass and under better illumination; soon too their feet will tire less, because "considerable research has so far led to the discovery of no satisfactory material which is less expensive to install than fitted carpet." And perhaps something will be done for the physically handicapped who find it difficult to climb some 50 steps from Trafalgar Square to the level of the main floor.

The improvements made or proposed, and the report on the activities of the Conservation and Scientific Departments become all the more interesting if read in the light of the account N. S. Brommelle has given of the state of affairs a hundred years ago (*Studies in Conservation* **2**, 176 (1956). The crowds were larger then (145,000 more in 1851 than 1953), and the resulting atmosphere, together with the effects of gas-light and wholesale combustion of coal well nigh rendered the pictures invisible. A system of air-conditioning similar to that in operation in the Houses of Parliament was proposed but a century was to pass before anything was done. There was also a suggestion, strongly supported by Faraday, that a chemist be appointed to investigate problems connected with preservation. He did not materialize until the present decade.

The conservation of works of art is a subject in which art and science must mix freely, but as the report shows, there are difficulties to be overcome, and the result is not always satisfactory. A reviewer of the earlier 1938-1954 report, displaying a not uncommon xenophobic attitude toward science, had complained about picture cleaning being decided solely by the "latest and fullest scientific analysis." This idea is discredited in the present report which points out that the role of the scientists at the National Gallery is advisory, all operations on paintings being carried out by restorers and craftsmen. That they cannot, however, ignore physics and chemistry, is evident in the Chief Restorer's contribution to the report, though the subjectivity of its approach suggests that it was not written for readers of this *Bulletin*. For example, it is not easy to understand the type of adhesion described on page 29, or the phenomenon of increased sensitivity to humidity variations which is acquired when a picture is maintained at constant temperature and humidity for four years, so that it reacts like "a senescent human who has been long kept indoors."

As it is to be expected, the section on the work of the Scientific Department is more restrained and objective, the most outstanding results being those obtained by the application of chromatography to the study of varnishes and paint media. There is reason to believe that these and other investigations, both at the National Gallery and elsewhere, will in time convince those who regard the intervention of the scientist in a sinister light of his true worth.

S. Rees Jones

MATHEMATICS AND COMPUTERS
By G. R. Stibitz and J. A. Larrivee

London and New York: McGraw Hill Publishing Co. Ltd. Pp. 228+vi. Price 37s. 6d.

George Stibitz, the senior author, has had a long and distinguished connexion with the computing machine field and the appearance of this book produced a pleasant sense of anticipation in the reviewer. Unfortunately a perusal of the work soon dispelled this feeling and led to observations which will be given later in this note.

The book is divided into eleven chapters and ends with bibliographies and author and subject indexes; chapter headings are: 1. Mathematics, Computers, and Problems, 2. Applied Mathematics and Solutions, 3. Kinds of problems and where they come from, 4. History of Computers, 5. Numerical analysis, 6. Digital computer components, 7. Logical design of digital computers, 8. Analogue computers and simulators, 9. Computing with random numbers, 10. Computing errors, and 11. Computers at work.

A major difficulty in evaluating the book is to decide upon the class of reader for whom it is intended; the dust jacket seems to

indicate that it is for professional mathematicians, scientists and engineers whilst the authors' preface takes a more modest stand and indicates the intelligent layman as the likely user. If the professional is intended then most chapters of the book have failed both because of the simple (not to say colloquial) style of the authors and because of the lack of solid facts. For the layman too there are grave defects, the assumption of a moderate knowledge of calculus and of previous technical acquaintance with the computer field for example. By and large it is probably fair to say that the most suitable readers will be American College students and graduates whose knowledge need be only superficial.

In many ways the book invites comparison with D. R. Hartree's *Calculating Instruments and Machines* but, unlike the latter, shirks any attempt to impart an understanding of the underlying principles. The only real attempt to describe a portion of a computing machine, the bi-quinary adder of pages 116-118, is made completely incomprehensible by the failure of the authors to indicate coils and contacts for the relays in Figure 6-7. Again, in Chapter 7, the "logical design" suggested by the chapter heading turns out to be a superficial account of a tape controlled computer which would not be regarded by most experts as typical of modern design. This tendency to conservatism compares ill with Hartree's refreshing treatment (*loc. cit.*) of nearly a decade ago where no attempt is made to infuse non-existent difficulties into Branching instructions as Stibitz and Larrivee do on p. 147.

For the technical non-expert the book has one excellent feature—Chapter 9 on computing with random numbers. The so-called Monte-Carlo methods for solving linear problems have not yet penetrated the educational system in this country and the authors have produced a very readable account of the subject which is illustrated by a number of clear examples.

There are a few errors, for example the first name in the second reference on p. 149 should be Hopper, and the right hand adder in Figure 10.1 should be a subtractor.

The book cannot be unreservedly recommended to English readers because of its high price and failure to compete with existing works in the field, but it is well produced and will probably find a place in the library of all specialists.

A. D. Booth.

ELEMENTS OF PARTIAL DIFFERENTIAL EQUATIONS

By I. N. Sneddon

London : McGraw Hill Publishing Co. Ltd. Pp. 327 + ix. Price 56s. 6d.

This new volume in the International Series in Pure and Applied Mathematics approaches the solution of partial differential equations through physics and engineering, and yet provides a sound, rigorous and up-to-date treatment of the subject that will satisfy most mathematicians. A modern outlook enlivens the book, and the many examples from recent work enrich it.

The first chapter deals with ordinary differential equations in more than two variables and includes Carathéodory's theorem and its application to thermodynamics. There follow chapters on partial differential equations of the first order and of the second order, which include all the well-known methods as well the use of integral transforms. The remainder of the book is devoted to the equations of mathematical physics, a chapter each to Laplace's equation, the wave equation and the diffusion equation, illustrated by a wealth of examples. A notable feature of the book, so unusual in a book emanating from the United States but not surprising as the author is British, is the large number of problems provided for the student. Another attractive feature is the use of vector calculus throughout.

It is an addition to mathematical literature that will be widely welcomed.

J. Topping.

MATHEMATICS AND WAVE MECHANICS

By R. H. Atkin

London : William Heinemann Ltd. Pp. 348 + xv. Price 30s.

This is a difficult book for a professional mathematician to review since it's neither aimed at him nor primarily at his students. In his preface the author says that: "Assuming the reader's mathematics is reliable at a level which he would normally reach prior to entering a University, I have tried to select a course of study which is logically connected and yet adequate for the pursuit of modern quantum theory. . . . It is my hope that it will consequently prove to be of value to physicists, chemists and those mathematicians who need an introduction to the subject." The ground covered in these 348 pages is quite astounding ; what is gained in breadth has obviously to be paid for in depth and your reviewer is in some doubt of the success of combining within such relatively small compass what amounts to a book of mathematical methods with one on wave mechanics.

The first 198 pages range over analysis, vectors, matrices, determinants, multiple integrals, differential equations, classical mechanics, vector field theory, wave motion and the electro-magnetic field. Despite the references to more complete works the danger is that the student should feel that this is all he need know of the mathematical background. If on the contrary it arouses interest by its very omissions then its purpose will be more than served.

The remaining 146 pages which one imagines form the prime purpose of the book introduce in the first chapter the fundamental concepts of quantum mechanics and then proceed through chapters on the wave equation, perturbation theory, the spin on the electron, quantum chemistry and the new statistics to the theory of the quantized field. The tendency here still is to a very condensed style particularly in the first of these chapters and it is here your reviewer feels that the book least measures up to its task, despite the many references given.

The main danger to be feared from the book is that it will be used for cramming purposes. If instead it is used by the student as the source from which his searches and researches into the subject may start then it will fulfil a most useful purpose.

L. HOWARTH.

ELEMENTS OF X-RAY DIFFRACTION

By B. D. Cullity

London : Academic Books Ltd. Reading, Mass : Addison-Wesley Publishing Co. Inc. Pp. 514 + xiv. Price 80s.

The purpose of this book is to teach the reader with no previous experience the elements of X-ray diffraction theory, techniques and applications. The method of teaching this subject undoubtedly depends on the type of audience, i.e. whether the students are physicists, chemists, metallurgists or mineralogists. This book has been written by a metallurgist, and naturally it will appeal most directly to metallurgists. This volume largely answers the need for a textbook suitable for metallurgy undergraduates, and forms an admirable basis for a lecture course to third year students in this subject. The book is in three parts :— (1) Fundamentals, (2) Experimental methods and (3) Applications.

The first part deals with properties of X-rays, the geometry of crystals and diffraction theory (directions and intensities). A clear account is presented of the latter, without the use of the reciprocal lattice.

Part II covers the experimental techniques of Laue and powder photography, and of diffractometry. Topics such as collimation, resolution and properties of different types of counters are discussed in detail.

Part III includes chapters on the orientation of single crystals by the Laue method, texture determination, indexing and interpreting powder photographs, accurate lattice parameter measurements, phase - diagram determinations, order-disorder transformations, stress measurements and chemical analysis by diffraction, fluorescence and absorption. Whenever possible the book has been kept up to date ; for example, both

photographic and diffractometer methods for determination of textures are described.

A number of appendices give crystallographically useful data ; a table containing both absorption coefficients and densities is particularly welcome.

The book contains many helpful diagrams, and also sets of questions at the end of each chapter.

An account of the reciprocal lattice and its properties is relegated to one of the appendices. In the reviewer's opinion this is unfortunate. A simple account of the reciprocal lattice should be well within the grasp of the average third year student, and prepares him for the more advanced parts of the subject, for which a knowledge of the reciprocal lattice is essential. A short and simple account of space group theory and single crystal methods for structure determination would also have been welcome.

Nevertheless the book fulfils a need which must have been felt by all those engaged in teaching X-ray diffraction to metallurgy students. It is to be warmly recommended and the author is to be congratulated on his lucid style and clear presentation of his subject matter.

P. B. Hirsch.

FUNDAMENTALS OF PHYSICS

By H. Semat

New York : Rinehart & Co. Inc. Pp. 941 + xii. Price $8.00.

This book is written for a thorough one-year introductory course in physics at college standard. It assumes no previous knowledge of physics and uses no calculus, but the treatment is rigorous and comprehensive. The notation is different in many places from that used in comparable books in England, but the material is beautifully presented and the diagrams are excellent. Each chapter ends with a good selection of numerical problems, to which, in an appendix, answers are given to the " odd-numbers," Answers to all the problems are available in a separate booklet. This device seems somewhat unnecessary at this stage. Several different systems of units are used with major emphasis on the c.g.s. system and the British engineering system, but the m.k.s. system is only mentioned in passing.

The physics presented here is about Advanced Level standard and it would be a useful book to have for reference in a Science Library.

Kathleen E. Parks.

ADVANCED CALCULUS

By R. Creighton Buck

London : McGraw Hill Publishing Co. Ltd. Pp. 423 + viii. Price 64s.

This book sets out to review elementary calculus with rigour, to give a systematic and modern approach to the differential and integral calculus of functions and transformations, and to derive analytical techniques for attacking some of the typical problems which arise in the applications of mathematics.

The properties of the real numbers are assumed, an appendix giving a brief review of foundation of the real number system and a statement of the main properties. The book opens with a chapter on elementary topology, then come in successive chapters, functions, integration, convergence, differentiation, applications to geometry and analysis, and lastly elements of differential geometry.

It is intended for students who have already taken a course in elementary calculus and Chapter 5 refers to differentiation of functions of more than one independent variable. The mean value theorems for one independent variable are introduced in Chapter 2 in connection with properties of continuous functions.

Throughout the emphasis is on more than one independent variable, functions being considered as dependent on a point in a suitable dimensional space. Though usually at most three dimensions are considered, the development is such as to make the transition to n dimensions natural and straightforward.

The definite integral is introduced by a detailed discussion of the double integral. In Chapter 7 the theory of differential forms is introduced, permitting a unified treatment of Stokes' and Green's theorems. The last chapter concludes with a brief introduction to the calculus of variations.

This book is well written and produced. It is full of examples, with answers and hints for solution at the end. It should be a useful book certainly for the special mathematics student in his final year or for the young graduate wishing to consolidate his fundamental knowledge. There must surely also be an increasing number of young physicists and engineers who would find a book such as this invaluable.

The more advanced mathematical techniques which are becoming increasingly necessary for the full appreciation of many developments in physics and engineering, demand for their proper understanding a more fundamental approach in the earlier stages. That this is becoming recognized in America is suggested by the author's statement in the preface that " there is a growing tendency in American colleges to present the elementary calculus from a more theoretical point of view." The book itself is based on mimeographed notes which were used for a two-semester course given to a mixture of mathematics, physics and engineering students.

Among a number of innovations in notation, the author consistently omits the differential in writing his integrals whenever he thinks no confusion can arise. This seems rather pointless when on many occasions it cannot be omitted without loss of clarity. Thus we have a theorem on p. 90 stated as : $\int_a^b f$ always converges if $\int_a^b |f(x)|\,dx$ converges. The physicist will, however, raise the more fundamental objection that the omission of the dx obscures the physical dimensions of the quantity.

Another minor criticism is that the formula for change of variable

$$\int_a^b f(x)\,dx = \int_\alpha^\beta f\{\varphi(u)\}\,\varphi'(u)\,du$$

is obtained from the indefinite integral (antiderivative), rather than as a transformation of the definite integral, the value being obtained as $F\{\varphi(\beta)\} - F\{\varphi(\alpha)\}$ where $F'(x) = f(x)$. It is then stated that for fixed a and b there may be a number of possible choices of α and β, any of which may be used if φ is continuous and differentiable on the entire interval $[\alpha, \beta]$. This is undoubtedly true but the point of criticism is that in cases such as $\int (1-x^2)^{\frac{1}{2}}\,dx$ it is almost impossible to get the correct result other than by considering the transformation of the definite integral. One shudders to think of the consequences if these two ideas were introduced at a more elementary level.

Nevertheless, with these reservations, the book is one that can be recommended to students wishing to revise their calculus from a more rigid viewpoint. A. W. GILLIES.

THE REDUCTION AND PRESENTATION OF EXPERIMENTAL RESULTS

By J. T. Richardson

British Standards Institution, B.S.2846. Pp. 44. Price 10s.

This book develops the theme that uniformity of procedure is essential, both in summarizing and comparing results obtained in the many determinations made in engineering production, and in other kinds of scientific and technological investigation.

Guidance is given on a wide range of types of experiments, e.g. in the laboratory or the factory, in research or in workshop production, in small or large scale observations, or in a series of repetitive tests such as those made for the quality control of products at different stages of manufacture.

A section of the book deals with the reliability of the results of an experiment expressed in terms of " confidence limits," i.e. the limits within which it is estimated that the true values of the arithmetic mean and the standard deviation lie, when associated with a stated probability.

The use of control chart techniques is briefly summarized and illustrated with examples.

SCIENCE AND THE NATION

By Sir Edward Appleton

Edinburgh : Edinburgh University Press. Pp. 104 + xi. Price 10s. 6d.

Sir Edward Appleton's Reith Lectures describe in simple language the organization

of British science and some of its recent achievements. The six chapters of *Science and the Nation*, corresponding to the talks originally given in the B.B.C. Home Service, are essays of about 4,500 words on separate but closely related topics. An introductory survey of the whole scene leads to a discussion of scientific problems tackled in the second world war. The major part of the book deals with the pursuit of science in industry, Government establishments and university laboratories. A final chapter summarizes well-established ideas on science and education

The lectures were written for a mass audience with little scientific knowledge or interest. They include nothing of any technical difficulty and do not refer to any of the controversial issues suggested by their title. Many physicists would have liked to hear Sir Edward's views on the conflict of morality and expediency in nuclear weapon tests, the allocation of resources for fundamental research between universities and Government laboratories and a host of other urgent problems—but *Science and the Nation* is not for them. It will be of interest to the parents and teachers designated by the author as his main target and should be made available to every sixth-form pupil, whether a science specialist or not.

J. M. A. LENIHAN.

IS PEACE POSSIBLE ?

By Kathleen Lonsdale

London : Penguin Books. Pp. 126. Price 2s. 6d.

Aldous Huxley wrote long ago that living is more difficult than sanskrit or chemistry or economics. In like measure many of the problems of national and world politics are more difficult than those of physics, but the time has indeed gone when we can pursue one set and shun the other.

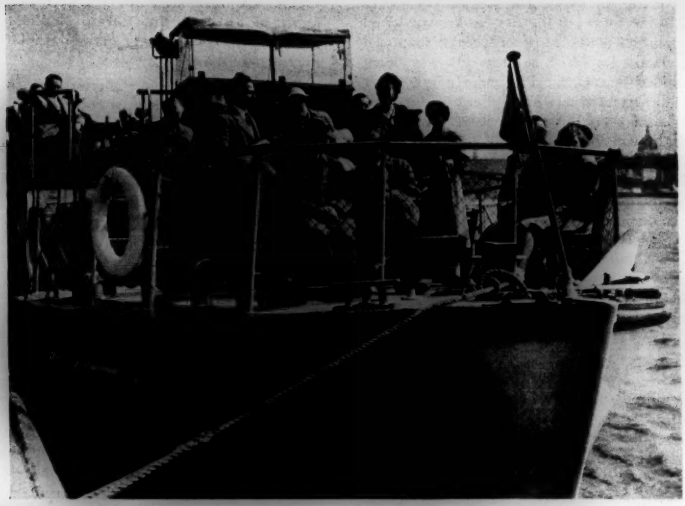
Kathleen Lonsdale in this little book faces with Quaker concern some of the major questions of our time, discusses them with directness and insight, and pleads for " that complete change of thinking that will be necessary if the world is to be saved from itself." It is written in a personal way, simply but not naïvely, enriched by a wealth of experience derived from much travel and much speaking in foreign lands, and strengthened and illumined by a strong Christian faith. Indeed it is an attempt to examine the pacifist witness of the Quaker community " against the background of modern science, of modern politics, of modern men and of future problems." The book is too short for the full treatment the subject merits and what is attempted is sketchy in places and somewhat uneven, but the author probably would not claim more than a desire to stimulate readers to think these problems afresh.

She first turns to world energy supplies and the increasing use of nuclear power and nuclear weapons, and the attendant health problems. How are we to avoid deterioration of human health and well-being ? Next she looks at the world population figures, the present rate of increase, the need for increased food supplies, but with living space and food-producing capacity limited. Where do excess populations overflow ? Is war inevitable, or can wise and generous attitudes towards under-developed (and some technically developed) countries lead to peaceful co-operation ?

Nuclear war is unthinkable ! She presses us to think of the consequences of testing and using hydrogen bombs, even of using small atomic weapons in minor wars.* She pleads for a World Court of Justice to replace the Security Council of the United Nations Organization in dealing with international disputes, for a new approach to economic and colonial matters, but above all there must be a change of attitude on the part of us all. " It is not enough only to take no personal part in war, although that is essential if conscience dictates such action. What is even more necessary is the deliberate building-up of an abhorrence of war as an evil thing." She re-echoes some words from the Atlantic Charter : " all nations of the world, for realistic as well as spiritual reasons, must come to the abandonment of the use of force."

J. TOPPING.

Branch and Group News



London and Home Counties Branch Summer Visit

Ninety members and guests of the London and Home Counties Branch assembled at Charing Cross Pier on the morning of May 22 in order to participate in the Summer Visit of the Branch to the Ford Motor Co. Ltd. at Dagenham. The party sailed to Dagenham on two river launches and enjoyed the panorama of famous pubs and power stations under the blue skies and excellent visibility accompanying the fresh dry north-easterly breeze.

Luncheon was taken on board, and thereafter the party disembarked at Ford's pier, and were received by the Company's representatives. A tour of the works followed, and most of the operations from the manufacture of pig iron in the blast furnace to the final inspection and adjustment of the finished vehicle were seen. The assembly lines for tractors and for "Zodiac," "Zephyr," and "Consul" cars were watched with interest, and after seeing the shining new cars being driven off every few minutes, the party returned to the launches for a welcome tea and the sail up the river to Charing Cross Pier. So ended another enjoyable Summer Visit which provided an opportunity of making new and renewing old friendships under pleasant circumstances.

J. S. Forrest.

Inaugural Meeting of The South Western Branch

The inaugural meeting of the South Western Branch took place in the Physics Lecture Theatre, Bristol University, on May 13. An appreciative and responsive audience of about 300 heard Professor H. S. W. Massey, F.R.S., deliver the inaugural address on "The Exploration of the Upper

Atmosphere using Rockets and Satellites." In a very crowded hour, Professor Massey fascinated his audience with an authoritative account of the exciting developments in this field. He surveyed the present knowledge of the physics of the atmosphere and discussed the means by which information was being extended by rockets. Particularly interesting and appreciated was his account of the satellites to be launched during the International Geophysical Year and the scientific data which it is hoped will be obtained by means of them. The address was followed by a short business meeting at which the rules of the government of the Branch were adopted and the officers and committee elected. These were Professor S. H. Piper (*Chairman*), Dr. N. Thompson (*Vice-Chairman*), Dr. S. H. Ayliffe (*Honorary Secretary*), Mr. K. G. Carr, Dr. K. E. Grew, Mr. A. H. Higgs, Dr. L. C. Jackson, Mr. H. F. T. Jarvis, Dr. H. A. Standing, Professor A. J. Woodall (*Committee members*). There followed a brief discussion in general terms concerning the future policy and program.

The new Branch will face problems on account of the scattered area which it will be required to serve, but the enthusiasm shown by the members at this first meeting gave a very encouraging start.

S. H. AYLIFFE.

Stress Analysis Group Annual Conference

The eleventh annual conference of the Group was held at Beaumont Hall, University of Leicester, on April 9, 10 and 11, 1957.

Fifteen papers were read, treating with a variety of topics associated with stress analysis. On the first afternoon the general theme was fundamentals, which from the point of view of this Group implies the physical aspects of stress on an atomic or microscopic scale.

Dr. Treloar gave a most interesting opening lecture on the structure of rubber-like materials and included some intriguing demonstrations. He was followed by Dr. Hirsch on dislocations in metals, and showing a cine film of actual dislocations doing all that for many years theory had predicted they ought to do. A paper on microstructure and fatigue and another on X-ray determination of stress completed the first session.

The A.G.M. of the Group was held in the evening. The following morning's session was concerned with the effect of elastic constants on photoelastic model results and criteria for design, also stress distributions in crankshafts and pin-fixed lugs.

The afternoon was most profitably spent in visits, one to Taylor, Taylor and Hobson's works where the whole process for making precision lenses was seen, and another to Jones and Shipman, where the manufacture of precision tools was explained. On return there were two photoelastic papers and after dinner an innovation to gather in specific groups to discuss particular topics, the idea being that a member with a particular problem could get the opinions and advice of other members.

V. M. HICKSON.

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE BOARD ON MAY 7, 1957

An asterisk (*) indicates transfer from another grade

FELLOWS

*Agar, Alan Wawn, B.Sc., Head of Laboratories, Aeon Laboratories, Englefield Green, Surrey.

*Bloomfield, George William, B.Sc., Ph.D., Divisional Physicist, National Coal Board, Durham.

*Copisarow, Alcon Charles, B.Sc., H.M. Scientific Attaché, British Embassy, Paris.

*Cowley, John Maxwell, Ph.D., D.Sc., Principal Research Officer, C.S.I.R.O., Australia.

*Croney, Ronald George William, B.Sc., Physicist, Bank of England Printing Works, Essex.

Duckworth, John Clifford, B.A., Deputy Chief Engineer, Central Electricity Authority, Leatherhead, Surrey.

Fraser, Robert Donald Bruce, B.Sc., Ph.D., Research Officer, C.S.I.R.O., Australia.

*Head, Alan Kenneth, B.Sc., B.A., Ph.D., Senior Scientific Officer, Aeronautical Research Laboratories, Melbourne.

*Lawley, Leonard Edward, B.Sc., Ph.D., Senior Lecturer in Physics, The Polytechnic, Regent Street, London.

*Pybus, Arthur Whitley, M.Sc., Principal Scientific Officer, Department of Supply, Weapons Research Establishment, South Australia.

*Sillitto, Richard Malcolm, B.Sc., Director of Studies in Natural Philosophy, University of Edinburgh.

Street, Robert, M.Sc., Ph.D., Senior Lecturer, University of Sheffield.

*Wyllie, George Andrew Park, B.Sc., Ph.D., Lecturer, University of Glasgow.

ASSOCIATES

Allen, John, M.Sc., Physicist, United Kingdom Atomic Energy Authority, Risley, Lancs.

Ashby, David Eric Thomas F., B.Sc., Scientific Officer, The General Electric Co. Ltd., Wembley, Middlesex.

*Brearley, Neil, B.Sc., Assistant Research Physicist, British Columbia Research Council, Vancouver, Canada.

Copley, Leonard John, B.Sc., Physicist, Rolls-Royce Ltd., Derby.

*Cowan, Ian Roy, M.Sc., Agriculture Research Officer, Manufacturers Association (of Jamaica Ltd.), Sugar Research Department.

Davies, Donald Noel, B.Sc., Research Assistant, Department of Physics, University of Edinburgh.

Davies, William Howard, B.Sc., Senior Physics Master, Central Grammar School, Manchester.

*Davis, Douglas Gerald, B.Sc., Research Engineer, Marconi's Wireless Telegraph Co. Ltd., Essex.

*Dawson, Thomas William Grant, M.A., Scientific Officer, Royal Aircraft Establishment, Farnborough, Hants.

de Reuck, Anthony Vivian Smith, M.Sc., Assistant Editor, *Nature*, London.

Doran, Gerald Anthony, B.Sc., Ph.D., Lecturer, University of Birmingham.

*Gaffee, David Ian, B.Sc., Senior Physicist, Power Samas Accounting Machines Ltd., Surrey.

*Hawkes, Leonard Frank, B.Sc., Physicist, Mullard Research Laboratories, Surrey.

*Henshaw, David Ernest, B.Sc., Lecturer, University of Western Australia.

*Hickson, Victor Morant, B.Sc., Senior Experimental Officer, Royal Aircraft Establishment, Farnborough, Hants.

Hinkley, Raymon, B.A., Chief Factory Engineer, Edison Swan Electric Co. Ltd., Gateshead, Co. Durham.

*Jenkinson, Arthur Eric, B.Sc., Physicist, Mullard Research Laboratory, Salford, Surrey.

Joel, Nahum, M.Sc. (Research Student, Cavendish Laboratory, Cambridge), Lecturer, University of Chile.

Jones, Neal Keith, M.Sc., Scientific Officer, Weapons Research Establishment, Victoria, Australia.

Keller, Andras, Research Fellow, University of Bristol.

Krause, Lucjan, B.Sc., M.A., Ph.D., Associate Professor of Physics, Memorial University of Newfoundland.

*Law, John, B.Sc., Technical Officer, Ferodo Limited, Chapel-en-le-Frith, Derby.

Le Roux, Pieter Louis Marchand, M.Sc., Physicist, Royal Marsden Hospital, London.

Love, Brian, B.Sc., Ph.D., Technical Assistant, Electricity Board of Northern Ireland.

Mason, William, B.Sc., Lecturer, College of Technology, Cardiff.

*Massam, Leonard Albert, B.Sc., Chief Chemist, Albert E. Reed & Co. Ltd., Kent.

*Moore, Alan, B.Sc., Ph.D., Scientific Officer, Atomic Weapons Research Establishment, Aldermaston, Berks.

Murray, Eric Lionel, B.Sc., Senior Research Scholar, University of Adelaide.

Newnham, Robert Everest, M.Sc., Ph.D., Research Worker, Cavendish Laboratory, Cambridge.

Nicholson, Angus Frank, B.A., M.Sc., Research Student, University of Birmingham.

Nikiforuk, Peter N., B.Sc., Ph.D., Defence Scientific Officer, Canadian Armament Research and Development Establishment.

Powell, Frank Baden, B.Sc., Senior Physics Master, Ebbw Vale County Grammar School, Monmouthshire.

*Randall, Denis David, B.Sc., Ph.D., Technical Officer, Imperial Chemical Industries Ltd., Scotland.

Rodmell, Eric Barnard, M.A., Senior Lecturer, Kingston Technical College.

Rutter, Robert Luke, B.Sc., Physicist, United Kingdom Atomic Energy Authority, Risley, Lancs.

Sanders, John Veysey, B.Sc., Ph.D., Senior Research Officer, C.S.I.R.O., Australia.

Shaw, John, B.Sc., Ph.D., Nuclear Physicist, Associated Electrical Industries Ltd., Research Laboratory, Aldermaston, Berks.

Shingler, Thomas, B.Sc., Member of Senior Staff, London Brick Co., Ltd., Bedford.

Smith, Ernest Edwin, B.Sc., Head of Statistics Section, Telephone Manufacturing Co. Ltd., St. Mary Cray, Kent.

*Som, Asok Kumar, M.Sc., Research Assistant–Physicist, Water Research Association, Surrey.

Thomas, Gordon Noel, B.Sc., Lecturer, Denbighshire Technical College.

*Thomas, Lancelot, B.Sc., Ph.D., Research Assistant, University College of Swansea.

Wells, Leonard Harvey, B.Sc., Head of Research Department, Ultrasonoscope Co. (London) Ltd.

Whittle, Robert Henry, M.A., Research Engineer (Aero Division), Rolls-Royce Ltd., Derby.

Williamson, Abel, B.Sc., Head of Physics Department, Bournemouth School, Hants.

*Zacharov, Basil, B.Sc., Senior Electronics Engineer, Rank Precision Industries Ltd., London.

GRADUATES

*Babb, John Michael, B.Sc., Valve Engineer, Standard Telephones & Cables Ltd., London.

Blackwell, Gordon Ralph, B.Sc., Research Physicist, Sir W. G. Armstrong Whitworth Aircraft Co. Ltd., Whitley, Coventry.

Blackwell, Mayveen Isobel, B.Sc., Assistant Mistress, Bald's Hill School, Coventry.

Brown, Roger Norman, B.Sc., Research Physicist, Imperial Chemical Industries Ltd., Plastics Division, Welwyn Garden City, Herts.

*Campbell, Alexander, M.A., B.Sc., Scientific Officer, United Kingdom Atomic Energy Authority, Risley, Warrington, Lancs.

Caplan, Henry Symon, B.Sc., Research Student, University of Glasgow.

Creagh, Audley Cecil, B.Sc., Research Fellow, University of Queensland.

Deakin, John Smith, B.Sc., Development Engineer, Joseph Lucas (Gas Turbine Equipment), Ltd., Birmingham.

Drake, Alan Rendal, B.A., Scientific Officer, Baird & Tatlock (London) Ltd., London.

Dudson, Malcolm Fox, B.Sc., Graduate Apprentice, Smith's Aircraft Instruments, Cheltenham, Glos.

Foster, James Edward, B.Sc., Technical Assistant, Vickers-Armstrong (Aircraft) Ltd., Weybridge, Surrey.

Gailis, Juris, B.Sc., Geophysicist, The British Petroleum Co. Ltd., London.

Gerald, Norman, B.Sc., Scientific Officer, The General Electric Co. Ltd., Stanmore, Middlesex.

Hakim Mohamed, Salah El-Din Abdel, M.Sc., Research Student, Chelsea Polytechnic, London.

Harbour, John, B.Sc.Tech., Research Student, College of Science and Technology, Manchester.

Isaak, George Richard, B.Sc., Research Student, University of Melbourne.

*Jackson, Brian John, B.Sc., Physicist, Electric and Musical Industries Ltd., Feltham, Middlesex.

*Jenkinson, Ivan Searle, B.Sc., University of Tasmania.

*Kendall, Bruce Reginald Francis, B.Sc., Research Student, University of West Australia.

Knights, Edith Jane, B.Sc., Technical Officer, Imperial Chemical Industries Ltd., Birmingham.

*Lowday, Howard Robert, B.Sc., Technician, Sir W. G. Armstrong-Whitworth Aircraft Co. Ltd., Coventry.

Luff, Douglas Reginald, B.Sc., Experimental Officer, Admiralty Materials Laboratory, Dorset.

MacInnes, Iain, A.R.T.C., Research Student, Royal College of Science and Technology, Glasgow.

McNeill, Deryk James, B.Sc., Research Student, University of Leeds.

Morris, Geoffrey Edward, B.Sc., Junior Physicist, De Havilland Propellers Ltd., Hatfield, Herts.

Mostafa, Mohammed Abdel Karim, B.Sc., A.R.T.C., Assistant Lecturer, Royal College of Science and Technology, Glasgow.

Pattenden, Stuart, B.Sc., Assistant Experimental Officer, United Kingdom Atomic Energy Authority, Harwell.

Ramanathan, Krishna, M.Sc., Postgraduate Student, Imperial College, London.

*Rampe, Bernard Colin, B.Sc., Electronics Engineer, Sir W. G. Armstrong-Whitworth Aircraft Co. Ltd., Coventry.

*Sheard, Frederick William, B.Sc., Research Student, University of Cambridge.

Simms, Keith James, B.Sc., Graduate Trainee, Salford Electrical Instruments Ltd., Salford, Lancs.

Skertchly, Allan, M.Sc., Assistant Lecturer, University of Leeds.

Smith, Peter Wolfgang, B.Sc., Scientific Officer, Admiralty Signals and Radar Establishment, Hants.

Steele, Ronald Leslie, B.A., Probationer Assistant, British Petroleum Co. Ltd., London.

*Walker, David Arthur, B.Sc., Assistant Experimental Officer, Atomic Weapons Research Establishment, Aldermaston, Berks.

Wallace, Kenneth Alexander, B.Sc., Scientific Officer, Atomic Weapons Research Establishment, Aldermaston, Berks.

*Whiting, Roy Stanley, B.Sc., Physicist, The General Electric Co. Ltd., Erith, Kent.

Yarranton, Arthur, A.R.C.S., B.Sc., Technical Assistant, H.M. Hobson's Ltd., Wolverhampton.

Young, Ian Gerald, B.Sc., Technical Assistant, Mullard Radio Valve Co. Ltd., Mitcham, Surrey.

The Institute's Journals

PRINCIPAL CONTENTS OF THE JULY, 1957, ISSUES

Journal of Scientific Instruments: Volume 34, No. 7

SPECIAL ARTICLE

The Physical Society's Exhibition—London, 1957. By E. J. Harris.

A survey is given of newer developments of instruments and apparatus exhibited.

ORIGINAL CONTRIBUTIONS

A low-frequency selective amplifier. By C. K. Battye (*Medical School, Guy's Hospital, London, S.E.1*).

The paper describes a selective amplifier having a frequency which is variable in steps between 1 and 1000 c/s, and a selectivity which can be set to values up to $Q=100$. The amplifier is d.c. coupled and employs a twin-T net, shunted by a capacitor, as a selective net in the negative feedback line.

Design and performance of a high-efficiency laboratory electro-magnet. By L. O. Bowen (*School of Applied Physics, N.S.W. University of Technology, Sydney*).

Major factors required in the performance of laboratory electro-magnets, namely field intensity and field homogeneity over accessible working volumes, have been achieved with moderate power consumption in an iron-clad magnet yielding power efficiencies [power efficiency $\propto$ (air-gap induction $\times$ air-gap)/ampere-turns] approximately 10% in excess of those obtained from similar magnets as previously reported. The magnet and support weighs 2½ t and operates from an 18 kW d.c. supply. Pole face diameters range from 11·5 to 1·5 in. with a range of air gaps from 5 to 0·5 in. Design procedure and data are reproduced.

Magnet current stabilizer for an electron spin resonance spectrometer. By R. J. Abraham, D. W. Ovenall and D. H. Whiffen (*Department of Chemistry, University of Birmingham*).

A description is given of a simple electronic stabilizer designed to supply an electromagnet with a current of 3 A, stable to one part in 3×10^4. Provision is made for the linear variation of this current with time.

A method of stabilizing the specimen temperature for single crystal X-ray crystallography. By D. E. Henshaw, Grad.Inst.P. (*Department of Physics, University of Western Australia, Nedlands, Australia*).

This paper describes a method for the automatic control of the specimen temperature in a single crystal X-ray goniometer for the growth and examination of crystals down to −130° C. The principle may also be useful for other temperature ranges.

The use of ferroelectric ceramics for vibration analysis. By R. C. Kell, A.Inst.P., G. A. Luck, A.Inst.P., and L. A. Thomas, F.Inst.P. (*The General Electric Co. Ltd., Wembley, Middlesex*).

The main advantage of ferroelectric ceramics of the barium titanate type for piezoelectric applications lies in their high dielectric constant, compared with the well-known single-crystalline piezoelectric materials such as quartz. Ferroelectric ceramics are used in accelerometers developed for the measurement of acceleration in vibration testing and in vibration strain gauges developed for the determination of the resonant frequencies of mechanical structures. The applications, construction and properties of these two devices are described.

The operation of a miniature camera by remote control. By D. E. Blackwell and D. W. Dewhurst (*The Observatories, University of Cambridge*).

The difficulties encountered in devising a mechanism for automatically winding and releasing the shutter of a Contax camera are discussed. A suitable clutch mechanism found to be satisfactory, is described.

A frequency modulated microwave spectrometer for electron resonance measurements. By A. C. Rose-Innes (*Services Electronics Research Laboratory, Baldock, Herts*).

An electron resonance spectrometer for use in the 3 cm microwave band is described. Use of a frequency

modulation method allows spectra to be recorded with simple equipment, and details are given of a special technique for increasing the sensitivity. The method is especially suitable for measurements at low temperatures and for the recording of wide lines.

A compressometer for obtaining stress strain curves of rock specimens up to fracture. By E. R. Leeman and C. Grobbelaar (*National Mechanical Engineering Research Institute, Pretoria, South Africa*).

A compressometer is described by which the axial compressive strains occurring in a cylindrical rock specimen subjected to a linear axial compressive load in a compression test, can be read or recorded continuously up to the point of fracture of the specimen. The measuring elements are U-pieces to which wire resistance strain gauges are cemented. The U-pieces are built into the compressometer in such a way that when the specimen to which the compressometer is attached, fractures, they fall unharmed from the compressometer. The instrument has been used to obtain the stress-strain curves of many rock specimens without its accuracy being impaired or suffering physical damage.

An automatic null method recording manometer. By H. R. B. Hack (*Experimental Station, Cheshunt, Herts*).

A brief account is given of a simple method of maintaining the position of the mercury meniscus of a manometer within less than 1 mm when pressure changes across the meniscus occur at a rate of up to 1 cm of mercury per minute. The limits of movement of the meniscus are determined by electrical contacts inserted through the manometer wall. The balancing of a pressure change across the meniscus is effected by the movement of a mercury reservoir raised or lowered by the rotation of a bobbin controlled by an electromagnetic ratchet relay. Each movement of the reservoir is recorded by an electromagnetic hammer.

A thermostat using a resistance thermometer and a galvanometer-photocell amplifier. By P. M. Hu, A.Inst.P., and R. W. Parsons (*Physics Department, University of Hong Kong*).

A very simple thermostat has been constructed and tested in a water bath up to 65°C. It has proved capable of keeping the temperature constant to within ±0·005°C. A salient feature is a simple d.c. voltage amplifier, using a robust galvanometer and two photocells which are connected in adjacent arms of a Wheatstone bridge. The amplifier has a gain of 5×10^5 and is sufficiently sensitive so that circuit operation will occur if the temperature changes by 0·001°C.

British Journal of Applied Physics: Volume 8, No. 7

SPECIAL ARTICLE

Summarized proceedings of a conference on electron microscopy—Reading, July, 1956. By C. E. Challice, F.Inst.P.

The annual conference of the Electron Microscopy Group was held in the Departments of Chemistry and Physics of the University of Reading on July 24–26, 1956. Papers covering the theory, construction, and application of the instrument were read, and in addition five papers on the applications of electron diffraction were presented.

ORIGINAL CONTRIBUTIONS

Some considerations of the magnetostrictive composite oscillator method for the measurement of elastic moduli. By N. B. Terry, A.Inst.P. (*Mining Research Establishment, National Coal Board, Isleworth, Middlesex*).

The development of the composite oscillator method, using nickel transducers, to enable measurement of the rigidity moduli as well as the Young's moduli of small cylindrical specimens is described. The magnitude of the cementing errors for the different modes of excitation is examined both theoretically and experimentally. An analysis is given which shows the advantages, for the technique described, of resonating at the fundamental mode for specimens of relatively low characteristic acoustic impedance. A further consideration of errors due to cross-sectional mismatch between transducer and specimen is made and finally some measurements on coal specimens are given.

The frequency dependence of noise temperature ratio in microwave mixer crystals. By M. E. Sprinks, A.Inst.P., G. T. G. Robinson and B. G. Bosch (*Electronics Department, University of Southampton*).

The contribution of flicker noise to the overall noise temperature ratio of microwave crystals has been widely noted and the previous estimates have shown that this contribution extends at least to frequencies of the order of 45 Mc/s. The normal range of inter-

mediate frequencies employed in radar receivers is 10 to 60 Mc/s.
The paper attempts to assess the rate of variation of noise temperature ratio and to indicate how the values would affect the overall receiver noise factor of a given system having an intermediate frequency lying within this range.

The impedance of the oxide-coated cathode at ultra-high frequencies. By L. J. Herbst, A.Inst.P. (*College of Technology, Birmingham*).

The impedance of the oxide-coated cathode has been measured on a number of disk seal triodes at frequencies ranging from 500 to 2365 Mc/s. Mean values of the parallel elements R and C_2 which constitute the coating impedance were 15 Ω ($\sigma = 0{\cdot}29\ \Omega^{-1}\ m^{-1}$) and 6·5 pF ($\epsilon = 3{\cdot}2$) respectively. The value of R decreased with increasing temperature. The temperature dependence of R was found from conductance measurements over a range of 150°K.

Fluoroscopy with an enlarged image. By R. Halmshaw, A.Inst.P., and C. Hunt (*Armament Research and Development Establishment, Ministry of Supply, London*).

Comparisons of attainable sensitivity have been made between two types of fluoroscopic set, one having an ultra-fine focus tube used with projective magnification and the other a conventional high current tube used with the specimen close to the screen. A marked gain in sensitivity was obtained with the former, values better than 1½% being obtained over a range of thickness of aluminium, and better than 3% on steel, using wire penetrameters.
Sensitivities have been calculated, in terms of the performance of the eye at different brightnesses and possible methods of improving sensitivity are considered.

The preparation of electron microscope replicas from rough porous surfaces. By D. M. Hall (*Dominion Physical Laboratory, Lower Hutt, New Zealand*).

A two-step collodion-carbon replica process is described for obtaining replicas from rough porous surfaces such as fractured teeth. Specimens are soaked in water and allowed to dry slowly so that a water block immediately below the surface prevents the collodion penetrating too deeply into the pores and ensures that the replicas can be stripped. The use of an amyl acetate/water interface to float the carbon replica while the primary collodion replica is being dissolved results in less damage to the carbon film than other methods used.

Size of the focal spot in a betatron. By D. Green, A.Inst.P. (*Betatron Research Group, Christie Hospital and Holt Radium Institute, Withington, Manchester*).

The X-ray source in a 20 MeV betratron has been examined and has been found to be about 1 cm wide. It is suggested that there are two X-ray sources, the small platinum target and the " donut " wall, to which electrons may be scattered from the target.
The resolving power of a finite sized ionization chamber is discussed in an Appendix.

The ultrasonic degradation of polystyrene at a frequency of 1 Mc/s. By N. H. Langton, A.Inst.P., and P. Vaughan (*The National College of Rubber Technology, Northern Polytechnic, London, N.7*)

Experimental results obtained by irradiating fractional polystyrene in benzene with ultrasonics of 1 Mc/s frequency are given. Degradation is observed to take place, and the consequent variation of degree of polymerization P with length of time of irradiation is shown. The results are compared with those obtained by other workers who used lower frequencies, and discussed with reference to the degradation equation of Schmid. An alternative equation which fits the experimental results better is examined.

The time-dependence of the recording properties of G5 nuclear emulsion. By W. C. Barron (*The Physical Laboratories, University of Manchester*) and A. W. Wolfendale (*Department of Physics, The Durham Colleges in the University of Durham*).

The fading of fast proton and μ-meson tracks in G5 nuclear emulsion has been studied as a function of time and conditions of storage. The storage time for a 50% reduction in the blob density of the tracks is estimated to be 1040 ± 200 days for storage at 5°C and 520 ± 50 days at 25°C. No difference in fading has been found between the emulsions stored in air and those stored in commercial argon. The mechanism responsible for the fading appears to be the thermal ejection of electrons from the latent image.
The sensitivity of the emulsion after storage has also been studied. A reduction in blob density of the tracks of fast particles of less than 5% after a storage time of 450 days has been found.

SOLID STATE COMPUTER COMPONENT RESEARCH

The Nelson Research Laboratories of the English Electric Co. Ltd. have vacancies for Physicists at Stafford. The work involves research into the design and development of new components for use in digital computers. Previous experience of semiconductor, magnetic or vacuum work would be an advantage.

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SIEMENS EDISON SWAN RESEARCH LABORATORY

Vacancies exist in the phosphors section of the newly-established Research Laboratory for Research Physicists and Assistants of degree standard, H.N.C. or equivalent qualifications. Vacancies also exist for Laboratory and Technical Assistants. The work is concerned with the study of photoconducting and luminescing materials and their use in the electronics industry. Successful applicants will be expected to reside in the Harlow area, where housing is available. Please write for application form to : Personnel Officer, Siemens Edison Swan Research Laboratory, c/o Associated Electrical Industries Ltd., Research Laboratory, Aldermaston Court, Aldermaston, Berks.

RESIN/GLASS DEVELOPMENT PHYSICIST or MECHANICAL ENGINEER. Graduate physicists or mechanical engineers, who are interested in the field of fibreglass reinforced plastics, are invited to apply for a vacancy in the Development Department of Fibreglass Ltd., St. Helens. The work will be primarily on the testing of mechanical properties of materials, and it would be an advantage if the applicant were conversant with techniques and equipment for specialized tests, including creep and fatigue. Applicants, who should preferably be not more than 35 years of age, are invited to send details of their qualifications and experience to the Personnel Liaison Officer, Pilkington Brothers Ltd., St. Helens, Lancashire, of whom Fibreglass Ltd., is a subsidiary company.

PHYSICIST required for laboratory work in connection with the development of domestic appliances. Candidates should have a good honours degree in Physics and have preferably had two or three years' industrial experience. There are good prospects in an expanding organization.
Apply Personnel Manager, Thorn Electrical Industries, Great Cambridge Road, Enfield, Middlesex.

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Applications (with copies of testimonials) should state age, qualifications, experience and research work completed or in progress and give the names of two referees whom the University may consult. Two copies of the application and testimonials should reach the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (from whom memoranda giving the general conditions of appointment and further information about the work of the department of Physics should be obtained) not later than July 31, 1957. An additional copy should be sent direct by airmail to the Registrar, University of Cape Town, Private Bag, Rondebosch, Cape Town, South Africa, by the same date.
The University reserves the right to appoint a person other than one of the applicants or to make no appointment.

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3. Applications Engineers : Two senior engineers, B.Sc. or equivalent, for valve and transistor applications, covering a wide range of electronic equipment.
4. Senior Circuit Engineer for radio and TV receiver development and/or varied industrial equipment.

Attractive salaries are being offered and terms and conditions of service at this "garden" site, within easy reach of Charing X, are excellent. Applicants should write with brief details in confidence to : W. J. Yeomans, Personnel Manager, Standard Telephones & Cables Ltd., Kolster-Brandes Ltd., Footscray, Sidcup, Kent.

Several attractive and Senior Positions are offered in the Development and Industrial application of modern non-destructive testing techniques. The positions will be in the following fields :

(1) Electronic Circuit Development
(2) Properties of Materials
(3) Physical Investigation and Measurement

They offer good scope to men of initiative and experience in the above fields. Salaries will be commensurate with the candidate's qualifications and experience.
Applications should be made in writing in the first instance, giving full details of qualifications, previous experience, age and salary required and be addressed to : Personnel Department, Kelvin & Hughes Ltd., New North Road, Barkingside, Essex.

UNIVERSITY OF READING

Applications are invited for a Lectureship in Theoretical Physics. Salary scale : £1,300 × £50 – £1,350 × £75 – £1,650. Candidates should possess sufficient experience and standing to enable them in addition to lecturing, to carry out independent research and to supervise the work of postgraduate students. Applications from persons not able to take up the appointment until October, 1958, may be considered.

Applications should be sent as soon as possible, and in no case later than September, 1957, to the Registrar (Room 9 O.R.B.), The University, Reading, from whom further particulars may be obtained.

BIRKBECK COLLEGE
(University of London), Malet Street, W.C.1
Session 1957/58

The postgraduate course in crystallography will commence on Monday, September 30. Up to 12 part-time (evening) students can be accepted for the degree of M.Sc. in crystallography (normally two years). The new teaching laboratory at 32 Torrington Square enables practical instruction to be given in all types of X-ray diffraction and ancillary equipment and in crystal physics. In addition to the basic training the lecture courses cover many special aspects of the subject from which a choice can be made. The course is adapted not only to the needs of students taking the M.Sc. examination in crystallography but also for students of physics, chemistry, geology, biological and engineering sciences, and those engaged in research and industrial laboratories who may need to use and understand crystallographic methods. Further information and a detailed syllabus can be obtained from the Secretary, Physics Department, Birkbeck College.

A limited number of D.S.I.R. advanced course studentships may be available to graduates of London University with a good honours degree in the Faculty of Science, which would enable them to take the examination after one year full-time study. Application forms for the session 1958/59, obtainable from the Secretary, Physics Department, Birkbeck College, must be returned to the Secretary not later than February 15, 1958.

COMMONWEALTH OF AUSTRALIA

AUSTRALIAN DEFENCE SCIENTIFIC SERVICE

AERODYNAMIC DIVISION

The Weapons Research Establishment of the Department of Supply, Salisbury, South Australia, invite applications for a position of

Senior Scientific Officer

from honours graduates in aeronautical engineering or science (physics and mathematics) or other academic qualifications and research achievements considered the equivalent. Several years postgraduate research experience required.

Salary : £2,103 – £2,268 (Australian currency).

Duties : Initiate and participate in research on aerodynamic and aerothermodynamic problems associated with supersonic and hypersonic missiles.

Location : Salisbury, sixteen miles from Adelaide, South Australia.

Whilst position is classified as temporary, tenure of employment is not limited and after a specified period, appointee will be able to apply for entry to Commonwealth Superannuation Scheme.

First class boat fare for appointee and dependants (wife and dependent children) will be paid under specified conditions by the Commonwealth of Australia. Assistance will be given with accommodation.

Application forms together with a descriptive leaflet obtainable from : Senior Representative (A.P.78), Department of Supply, Australia House, Strand, London, W.C.2, with whom applications should be lodged by July 22, 1957.

COMMONWEALTH OF AUSTRALIA

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

DIVISION OF SOILS

Appointment No. 270/159 Soil Stabilization

Applications are invited from Engineers, Physicists and Chemists who may be interested in co-operating in a programme of fundamental and applied research in several aspects of soil stabilization.

The organization's division of soils is about to undertake a general investigation into the principles and practices of soil stabilization with particular reference to the ranges of soils, environments and construction conditions applicable to Australia. It is hoped to develop a team of research workers (including existing staff of the division) embracing all of the necessary disciplines of soil science and of soil mechanics appropriate to this subject. The appointee will be located in Melbourne, Victoria.

Applicants should possess a University honours degree in science or engineering together with several years research experience, preferably in soils stabilization or related fields.

Dependent upon qualifications and experience commencing salary will be determined within the salary ranges of Research Officer £A1,313 – £A1,938 per annum or Senior Research Officer £A2,048 – £A2,323 per annum. Salary for a female appointee would be £A167 per annum less than the corresponding male rate. The Officer responsible for this project will be available in London from June to September for any discussions on details of the intended research programme.

First class sea fare to Australia will be paid for the appointee and his wife and family.

The appointment will be conditional upon a satisfactory medical examination and the appointee will be required to contribute to, and eligible to receive benefits from, either the Commonwealth Superannuation Fund or the Commonwealth Provident Account.

Applications, quoting Appointment No. 270/159 and stating full name, place, date and year of birth, marital state, present employment, particulars of qualifications and experience and of war service, if any, accompanied by copies of not more than four testimonials, and the names and addresses of at least two persons willing to act as referees, if required, should reach the undersigned, from where further particulars may be obtained, by August 9, 1957.

A. Shavitsky,
Chief Scientific Liaison Officer.

Australian Scientific Liaison Office,
Africa House,
Kingsway,
London, W.C.2.

CENTRAL ELECTRICITY AUTHORITY

NUCLEAR POWER SUB-DEPARTMENT

invite applications for posts in the instrumentation and health physics section in London, S.E.1, from persons having a degree in physics or electrical engineering (or equivalent) and, preferably works or laboratory experience, for work on reactor instrumentation and control.

Specialized training will be given if necessary.

Salaries within scales £870 – £1,795 p.a. according to ability. Application forms obtainable from D. Moffat, Director of Establishments, Winsley Street, London, W.1, to be returned by July 20, quote ref. P.B./284.

MIDDLESEX COUNTY COUNCIL
Education Committee
Brunel College of Technology
Woodlands Avenue, Acton Hill, W.3
Opening in September, 1957

Applications are invited for the following :

Senior Lecturer in Electronics. The person appointed will be responsible for all the work in electronics in the college including full-time, sandwich and part-time courses as well as postgraduate courses and research. The post is one of special responsibility for the work of the electronics division of the college and carries a salary of £150 higher than the maximum of the Senior Lecturers' scale.

There is an opportunity to develop courses in electronics, particularly for physicists and engineers, to the highest standards. Candidates should be well qualified in electronics and have appropriate industrial, research and teaching experience. Ability to direct research in some branch of electronics will be an added qualification.

Salary in accordance with the Burnham (Technical) Report, 1956, i.e. Senior Lecturer—£1,350 × £50 – £1,550 per annum plus London allowance.

Further particulars and forms of application (stamped addressed foolscap envelope) from the Clerk to the Governing Body, Brunel College of Technology, to whom completed forms must be returned not later than July 26.

C. E. Gurr, M.Sc., Ph.D.
Secretary to the Education Committee.

WANTED
SCIENTIFIC PERIODICALS
AND BOOKS
IN ALL LANGUAGES
GEORGE S. H. PEALL, M.I.E.S.
64 NORTHEY AVENUE, CHEAM, SURREY

CENTRAL ELECTRICITY AUTHORITY
NUCLEAR POWER SUB-DEPARTMENT

invite applications for posts in the Reactor Design Sub-Branch from persons having a degree in physics, chemistry or electronic engineering (or other suitable qualification) and, preferably works or laboratory experience, for work in the field of Health Physics. Successful candidates will eventually be based at a nuclear power station site after completion of training course. Salaries within scales £550 – £1,735 p.a. according to ability. Application forms obtainable from D. Moffat, Director of Establishments, Winsley Street, London, W.1, to be returned by July 20. Quote ref. P.B./285.

Courses

THE POLYTECHNIC,
309 REGENT STREET, W.1.

DEPARTMENT OF MATHEMATICS AND PHYSICS

Full-time and part-time day courses are available for B.Sc. General in pure mathematics, physics and applied mathematics or statistics, B.Sc. Special in physics and Grad.Inst.P.

Evening courses are offered in B.Sc. General, statistics, electronics, techniques of mathematical physics and postgraduate mathematics.

Prospectuses may be obtained from the Director of Education.

BATTERSEA COLLEGE OF TECHNOLOGY

Microwave Physics — The following courses in Microwave Physics for part-time and evening students will commence in October, 1957 : (*a*) M.Sc. degree of the University of London, (*b*) The post-graduate diploma of the College, D.C.T. (Batt.), (*c*) Postgraduate on (i) Microwave theory, (ii) Microwave techniques and measurements.

Application forms and further details may be obtained from the Secretary (Microwave Course), Battersea College of Technology, Battersea Park Road, London, S.W.11.

PRINTED BY F. J. MILNER AND SONS LIMITED, COMMERCE ROAD, BRENTFORD, MIDDX.

Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

Several attractive and Senior Positions are offered in the Development and Industrial application of modern non-destructive testing techniques. The positions will be in the following fields :

(1) Electronic Circuit Development
(2) Properties of Materials
(3) Physical Investigation and Measurement

They offer good scope to men of initiative and experience in the above fields. Salaries will be commensurate with the candidate's qualifications and experience.
Applications should be made in writing in the first instance, giving full details of qualifications, previous experience, age and salary required and be addressed to : Personnel Department, Kelvin & Hughes Ltd., New North Road, Barkingside, Essex.

RESEARCH OFFICERS are required by the Heating and Ventilating Research Council at their Leatherhead Laboratories, Surrey, for investigation of basic problems in the field of heating and ventilation. This Council receives support from the Department of Scientific and Industrial Research. Applicants should be physicists or engineers of graduate or equivalent standard and should be familiar with experimental methods and measuring techniques. Previous experience in heating and ventilation is not essential but some knowledge of either heat transfer, fluid flow, automatic control or instrumentation would be an advantage. Excellent opportunities for advancement. Superannuation. Five-day week. First rate facilities. Salary to be negotiated. Write giving full details to : Secretary, Heating and Ventilating Research Council, c/o B.C.U.R.A. Laboratories, Randalls Road, Leatherhead, Surrey.

DEVELOPMENT ENGINEER required as head of a section engaged in development work on capacitor dielectrics. A graduate or A.Inst.P. with a working knowledge of statistics and of practical electrical measurements. The post is an interesting and responsible one with considerable prospects. The commencing salary will be within the range £1,000 to £1,500 or more according to qualifications and experience. Please write full details to Personnel Manager, Telephone Manufacturing Co. Ltd., Sevenoaks Way, St. Mary Cray, Kent.

BRITISH PLASTER BOARD (Holdings) LTD., East Leake, Mr. Loughborough, Leics., need a physicist, preferably of Ph.D. standard for basic research and development of technological problems; some experience an advantage but recent graduates considered. The laboratories, which are new, are situated in East Leake, equally convenient for Nottingham, or Loughborough. Salaries in accordance with age, qualifications and experience. Non-Contributory staff pension scheme. Write for form of application to Controller of Research quoting Tech. Phys/KS.

PILKINGTON BROTHERS LTD., who are the largest manufacturers of plate and sheet glass in the British Commonwealth and employ more than 20,000 persons, wish to appoint a Head of their Technical Development Department. This is a new appointment necessitated by the large number of development projects in hand. It is intended that the man selected should take charge of the development of new processes and the radical improvement of existing ones. There are ample technical resources available and the Company spends large amounts on development work. Applicants must have a good honours degree in engineering, physics or chemistry. They must also have a flair for development work, and the enthusiasm to see a job through. Applications will be welcomed from men aged preferably 35/45 who have done at least five years' successful and original development work in industry or at a university. The Company is prepared to offer a Service Agreement at an attractive salary to the right man.

All applications will be treated confidentially and should be addressed to the Group Personnel Officer, Pilkington Brothers Ltd., The Glass Works, St. Helens, Lancashire.

IMPERIAL CHEMICAL INDUSTRIES LTD.

Billingham Division

PHYSICISTS

LIGHT CURRENT ELECTRICAL ENGINEERS

Imperial Chemical Industries Ltd., Billingham Division, has several interesting vacancies for Physicists. The Division has an expanding research programme and requires physicists to carry out work on the development of physical methods and techniques and their application to chemical problems and analytical methods.
There is also a requirement for Physicists and Light Current Electrical Engineers who have made a broad study of instrument technology or who wish to take up work in the fields of instrument development and management.
Candidates should be not more than 32 years of age and hold an honours degree. These appointments are pensionable and there is a profit sharing scheme in operation. Starting salaries will depend upon qualifications and experience. Write giving brief details of age, qualifications and experience to the Staff Manager, Imperial Chemical Industries Ltd., Billingham Division, Billingham, Co. Durham, quoting reference W/P/4.

I. C. I.

GENERAL CHEMICALS DIVISION

PHYSICIST

A well-qualified Physicist is invited to help in research work covering specialized physical measurements, infra-red spectroscopy, mass spectroscopy and ultrasonics. This should prove to be an exciting vacancy for a man with ideas who is anxious to publish original work.

The salary structure of the Company provides for rapid rise to the maximum at any particular grade. Starting salaries depend on age, qualifications and experience, and there is ample opportunity for further advancement.

The Company operates Pension and Profit-Sharing Schemes and provides first-class social and recreational facilities.

The successful candidate will, if married, receive a refund of his reasonable removal expenses and will also be paid a generous lodging allowance for a period not exceeding six months whilst he is maintaining two homes. In addition he will be eligible for assistance towards house purchase.

Applications, giving particulars of age, qualifications and experience, should be made in writing to :— **Staff Manager, Imperial Chemical Industries Limited, General Chemicals Division, Cunard Building, Liverpool 3, quoting reference RPH24.**

UNIVERSITY OF NATAL

SOUTH AFRICA

Applications are invited from suitably qualified persons for appointment to the vacant Chair of Mathematics at the Pietermaritzburg or Durban centres of the University.

The salary scale attached to the post is £1,400 × £50 – £1,600 per annum. This scale is at present under review. In addition, a temporary cost of living allowance of £234 per annum is paid to married men only. Application forms and further particulars of the post are obtainable from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

Applications close in South Africa and London on September 14, 1957.

THE BRITISH THOMSON-HOUSTON CO. LTD.

The British Thomson-Houston Co. Ltd., has vacancies for physicists in a group carrying out investigations into the properties of semiconducting materials. The work will be mainly concerned with the physical properties of rectifiers and associated devices, and offers wide experience in both fundamental and applied research in a rapidly expanding field.

Applicants are invited to write to the Director of Research, The British Thomson-Houston Co. Ltd., Rugby, stating age, qualifications and experience and quote reference SJ.

THE BRITISH THOMSON-HOUSTON CO. LTD., has vacancies in its Lamp Engineering Department for scientists and technical assistants for all aspects of work (physics, chemistry and engineering) connected with the development of electric filament and discharge lamps. The work offers interesting careers at various levels to those with qualifications ranging from an honours degree to O.N.C., and will be either at Leicester or in the north London area. Applicants are invited to write to the Manager, Lamp Engineering Department, The British Thomson-Houston Co. Ltd., Rugby, giving details of their age, qualifications and experience, quoting reference TA.

COURSES

NORTHERN POLYTECHNIC

Session 1957-58

Advanced Courses in

Electronics and Microwave Physics

Electrical Discharges in Gases

Solid State Physics

Suitably qualified students can proceed to the M.Sc. degree of the University of London. Session commences September 23, 1957.
Also short lecture courses on :

Introduction to Electronics and Microwave Physics—commencing October 2, 1957.

(This is designed for graduates requiring basic electronics for industrial applications).

Transmission Lines—commencing October 2, 1957.

Mathematics of Circuit Analysis—commencing October 2, 1957.

Wave-Guides—commencing November 6, 1957.

Amplifiers—commencing November 6, 1957.

Enquiries should be addressed to :

Head of Department of Physics,
Northern Polytechnic, Holloway,
London, N.7.
(Telephone : NORth 1686)

THE UNIVERSITY OF SHEFFIELD

Six Research Bursaries are available in the Department of Fuel Technology and Chemical Engineering for graduates in Physics, Mathematics, Chemistry, Chemical Engineering, or other engineering subjects, who wish to enter the important field of flames and fuels. The work relates to heat transfer from flames and furnace aerodynamics. Value in the range £300–£500 per annum plus research fees. Bursars may become candidates for higher degree of the University. Applications should be sent to the Registrar as soon as possible.